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World Mining

NOVEMBER 1981
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THE COVER

Tin dredge operating in Malaysia. Malaysia is the foremost tin producing country in the world with a mine output last year of 61,400 metric tons of tin in concentrates, a little less than a third of the total free world output. Last month the country played host to the Fifth World Conference on Tin, which was held in Kuala Lumpur. The conference came at a particularly opportune time as the preceeding months had seen significant increases in the trading price of tin. *Photograph courtesy of the Malaysian Mining Corporation Group.*

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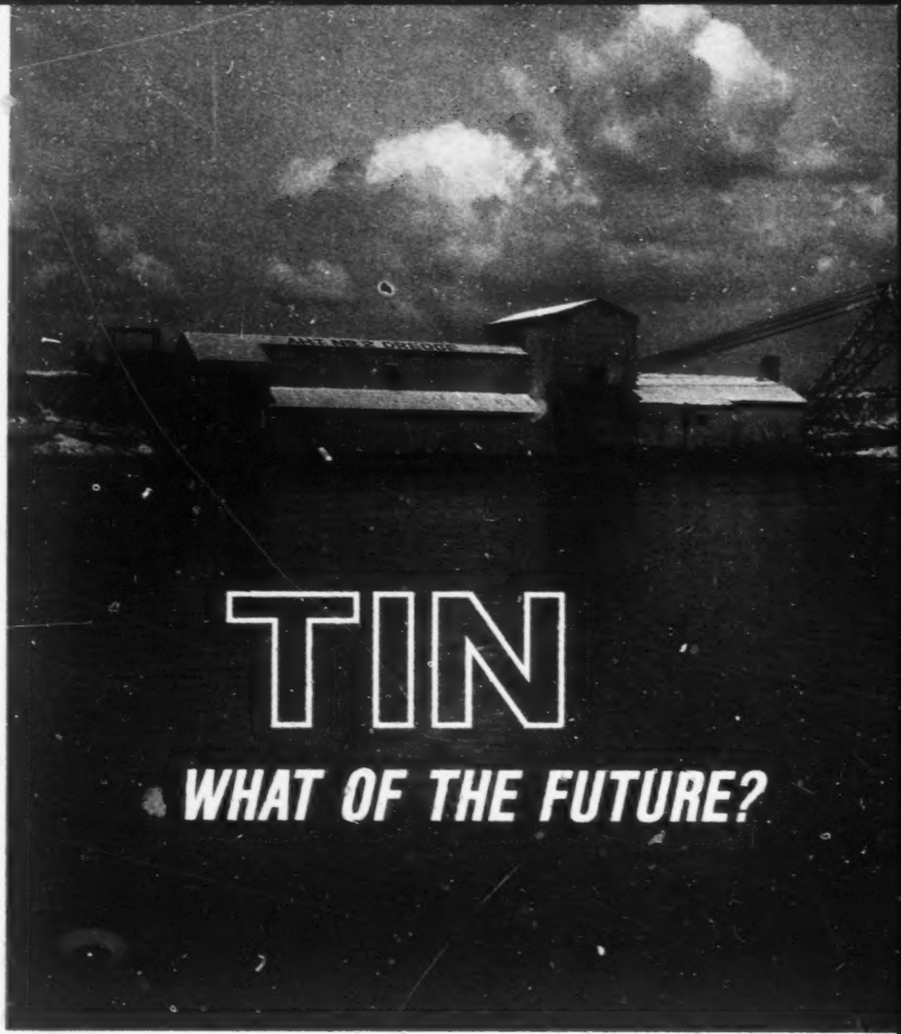


TIN

WHAT OF THE FUTURE?

By **John R. Chadwick**
Associate Editor

At the beginning of May, the cash price for tin on the London Metal Exchange (LME) was around £5,900 per metric ton. At the beginning of July it was £6,600, since when it rose steadily, reaching £8,400 at the end of September. However, demand for the metal was low and the LME warehouse stockpile stood at around 13,000 tons, one of its highest levels ever. The international tin market was definitely intriguing and the stage was set for the Fifth International Conference.

Western world tin production in 1980, including exports from China, amounted to some 203,000 tons and the average prices per ton for the year were £7,228 or 35,700 Malaysian dollars. Current world consumption of primary tin metal is around 180,000 tons per year.

Delegates for the Fifth World Conference on Tin gathered in Kuala Lumpur, capital of Malaysia, in late October. This of course was a particularly fitting venue since Malaysia is the world's leading producing country with a mine output last year of 61,400 metric tons of tin in concentrates.

At the previous four conferences, there was little discussion about the financial and economic aspects of the tin producing and consuming industries. The broad aim of this conference was to review new production resources and consumption potential not simply in the light of the technology required for extraction or development, but also from the financial and economic viewpoints, with particular emphasis being placed on the investment that will be required to realize that potential. The intent was to cover the medium-term outlook of both the tin producing and consuming industries. These were indeed sound ideals in the light of the trends that dominated the industry at the beginning of 1981: rising production costs; a downward trend in world prices; sales from the United States strategic stockpile that posed a threat to the supply/demand situation; and problems in reaching a new International Tin Agreement. The Sixth International Tin Agreement has subsequently been drawn up and will come into force on July 1, 1982.

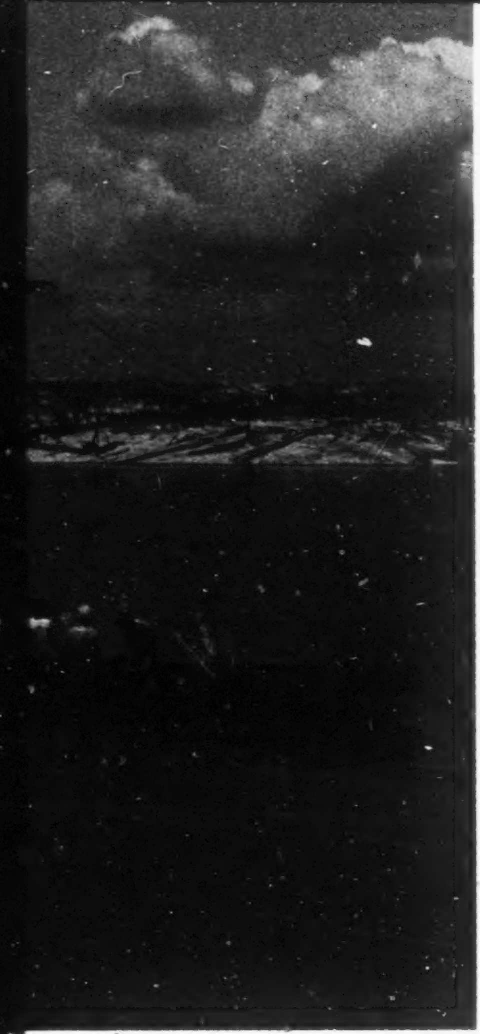
The conference papers were divided into four sections covering: production (new discoveries) and new production technology; consumption potential; marketing, aspects and outlook; and investment. Finally, a panel selected from among the participants discussed investment questions that arose during the conference.

The first paper, "The world tin economy and new trends" by A. La Spada, set the stage for the conference. The majority of the world's tin-bearing ores are mined in the equatorial regions of southeast Asia, Africa, and Latin America. Few of these countries are important consumers. Most tin is consumed in North America, Europe, and Japan and it is therefore widely traded between producing and consuming countries. Significant quantities of concentrates are also produced in the Soviet Union, China, Australia, and the United Kingdom. Some important figures from La Spada's paper are shown in Tables 1, 2, and

Table 1.
Production of primary tin metal

	1976	1977	1978	1979	1980
Australia	5,600	5,600	5,100	5,400	4,700
Bolivia	9,800	13,000	16,200	15,700	18,500
Indonesia	23,300	24,000	25,800	27,800	30,500
Malaysia	78,000	66,300	72,000	73,100	71,300
Nigeria	3,700	3,300	3,000	2,900	2,600
Thailand	20,300	23,100	28,900	33,100	34,700
Zaire	500	700	900	500	900
Sub-total	141,200	136,000	151,900	158,500	163,200
Percentage	77.4	75.6	78.5	78.8	81.1
Belgium/Luxembourg	4,100	3,500	3,300	2,200	2,800
Brazil	6,400	7,400	9,300	10,100	8,100
Netherlands	2,000	2,100	1,600	1,700	1,100
Singapore	—	—	1,500	4,000	4,400
Spain	5,400	5,300	4,600	4,400	4,200
United Kingdom	11,200	10,100	8,400	8,000	5,900
United States	5,700	6,700	3,900	4,500	3,900
Sub-total	34,800	35,100	32,600	34,900	31,100
Percentage	19.1	19.5	16.8	17.3	15.5
Others	6,500	8,800	9,000	7,800	6,900
Percentage	3.5	4.9	4.7	3.9	3.4
World[1]	182,500	179,900	193,500	201,200	201,200

[1] Excluding mainly East Germany, China and the Soviet Union.



3. These cover production, consumption, and costs.

The second paper, "Tin production and investment" by B. C. Engel, reviewed and updated the work of the Committee on Development of the International Tin Council, which recently undertook a study on tin production and investment. The study was published in 1980 and reviewed in WORLD MINING (September 1980, page 111). In a later issue (WORLD MINING, October 1980, page 86) some very interesting production cost figures from the same report were published.

D. P. McIntyre and S. M. Richards, both of Aberfoyle Ltd., reviewed "Investment in Australia's future tin resources." They stated that hard rock reserves will continue to be the source for most tin output over the next ten years. Research and development will concentrate on improving recovery through preconcentration techniques, flotation, and possibly fuming. Constraints on new mine developments are the exchange rate of the Australian dollar and the costs of labor, energy, and construction. These factors favor the expansion of existing mines and developments in their vicinity rather than the development of new mining areas. Any new developments are likely to be open pit mines at grades of 0.5 percent Sn or higher. Favorable metallurgical characteristics will also be an important consideration.

Table 2.
Consumption of primary tin metal

	1976	1977	1978	1979	1980
Australia	3,600	3,800	3,600	3,400	3,000
Belgium/Luxembourg	3,000	3,300	3,100	2,400	2,700
Canada	4,800	5,300	4,900	4,700	4,800
Czechoslovakia	3,500	3,100	3,200	3,200	3,200
France	10,200	10,700	9,900	9,700	10,100
West Germany	14,800	14,100	13,500	13,700	14,300
India	3,000	2,700	2,600	2,500	2,500
Italy	5,900	6,200	5,800	6,000	6,500
Japan	34,700	29,700	29,600	31,200	31,200
Netherlands	3,800	4,900	4,800	4,800	5,000
Poland	5,100	4,700	4,600	3,900	3,300
Romania	3,100	3,200	3,200	3,200	3,300
Spain	4,600	3,700	4,500	4,100	4,300
United Kingdom	13,500	12,700	12,200	11,100	7,800
United States	51,800	47,600	48,400	49,500	46,000
Sub-total	165,400	155,700	153,900	153,400	148,000
Percentage	85.3	84.3	83.6	83.7	83.4
Others	28,600	29,100	30,100	29,900	29,400
Percentage	14.7	15.7	16.4	16.3	16.6
World[1]	194,000	184,800	184,000	183,300	177,400

[1] Excluding mainly East Germany, China and the Soviet Union.

Table 3.
Weighted average of tin production costs and prices in Malaysian dollars per pikul

	1976	1977	1978	1979	1980[2]
Average cost[1] yearly	1,000	1,264	1,408	1,534	1,824
Index (1971 = 100)	179	227	252	275	327
Average tin price (Penang) yearly	1,147	1,588	1,743	1,961	2,160
Index (1971 = 100)	181	251	276	310	342

[1] Including royalties, export duties, and tributes. [2] Provisional figures.

Tin production in Brazil has been increasing significantly over the last five years as a result of major exploration investment, mainly in the Amazon region. "New tin discoveries in Brazil" were reviewed by J. R. M. Franco. A major deposit containing 23,000 tons of tin has been discovered on the Pitinga River on the north bank of the Amazon basin, 300 kilometers (186 miles) north of Manaus. Surucucus is another important recent discovery. This tin deposit is situated to the west of Roraima Federal Territory in northern Brazil. Garimpeiros (pick-and-shovel miners) had produced 563 tons of tin concentrate over a 14-month period. However, mining has been suspended for the time being because of troubles between the miners and local Indians.

Goiás Mineracão is carrying out an intensive exploration program in the Serra Dourada. The company expects to invest $4,000,000 in the next three years to evaluate an extensive tin ore body. The Paranapanema group has invested some $3,700,000 to develop the important São Raimundo deposit in the southern central Pará State, on the Xingú River. Exploration results to date have shown an alluvial deposit with reserves of 3,407 tons of tin, at a grade of 0.408 kilograms Sn per cubic meter (0.688 pounds Sn per cubic yard). Open pit mining is proceeding with a production rate of some 3 tons of cassiterite a day.

The major discoveries over the last 10 years in Indonesia have been offshore reserves, greatly benefiting this country's output. Important deposits have been discovered in the Kundur Sea. Onshore, the discovery of the Tempilang deposit is regarded as significant since it is of a type to which very little attention has been paid hitherto. It is hoped that development of both sources will begin soon. In their paper, "Review of discoveries of new tin deposits in Indonesia," S. Sujitno and M. Simatupang describe the geology of these deposits and review current exploration work.

New discoveries of deposits and occurences, both onshore and offshore, including geochemical anomalies, were summarized by S. S. Rajah and D. S. Singh in "Discoveries of tin deposits and occurrences in Peninsular Malaysia during 1974 to 79." The present status and future prospects of the industry were presented as well as recommendations for exploration targets.

"Possible future tin mining activities and possible new mines in Nigeria" were covered by I. Gombe. Alluvial sources have, hitherto, provided all the cassiterite mined in Nigeria, but annual production over the last decade has fallen from 11,200 to below 4,000 tons. The major reasons for the decline are the depletion of easily mined high value alluvial reserves, the slow introduction of mechanization, increased operating costs, and the absence of alternative reserves.

Primary deposits offer good prospects to expand reserves and the Nigerian Mining Corporation is actively exploring such possibilities. Additionally, there are large known reserves of sub-basalt cassiterite and the prospect for further such reserves is high. These two sources offer great potential for production expansions. Similarly future exploration is expected to increase alluvial reserves and activity in that sector.

S. Kulvanich's paper, "Offshore exploration for tin in Thailand," reviewed an exploration program for tin and heavy minerals in deep water, 30 to 45 meters (98 to 148 feet), in the Andaman Sea, southwest of Thailand. The first phase of the project involved the compilation of geological data and a geophysical investigation, and gave promising results. A supplemental drilling program is now underway to determine the distribution, extent, and characteristics of the prospects.

Zaire is another country where tin output declined dramatically, to below 4,000 tons a year, over the last decade. A paper prepared by that country's Department of Mines outlined "Tin in Zaire and its prospects for the future." The government has produced a recovery plan aimed at improving production and conditions, increasing research and exploration, and optimizing recovery profitability. Sominki, operating in the Kivu-Maniema region and Zairetain, operating in Shaba province, are the main producers. A new company, SMDG, has started mining small alluvial deposits. Société Minière de Katondo and Société Minière de Kania will commence tin mining in the future, while Enterprises Minières Zairoises (Emza) is to restart tin mining operations.

"The Kuala Langat tin field" was examined by Yap Cheng Hock. The area already includes active mines in the Dengkil area of Selangor but the development of the deep ore body in Brooklands Estate and the Forest Reserves to the south will increase Kuala Langat's importance in the future. The paper outlined exploration undertaken between 1973 and 1975 and the problems encountered. Multiple mineralization sources, from the granite contact zones at Ayer Hitam in the north and Sungei Besi and Kajang in the northeast, are suggested as well as at least three phases of mineralization.

The South Selangor, or Kuala Langat, deposit is the world's largest known tin reserve, estimated to contain more than 200,000 tons of tin. It is covered with overburden varying in depth from 20 to 30 meters (60 to 100 feet). The ore body itself varies in depth between 50 and 100 meters (150 to 300 feet). This great depth requires "An alternative method for mining deep alluvial ore deposits," as described by J. M. Donkers.

The new concept employs a suction dredge, equipped with a dredging wheel capable of recovering paydirt from a depth of 100 meters (300 feet), and a bucket line dredge for removing the overburden. The combined throughput would be in excess of 19,000,000 cubic meters (25,000,000 cubic yards) per year. Donkers' discussed the proposed equipment, a possible mine plan, and capital and operating costs. The possibilities and limitations of a variation of the dredging wheel dredge for offshore mining applications were also covered.

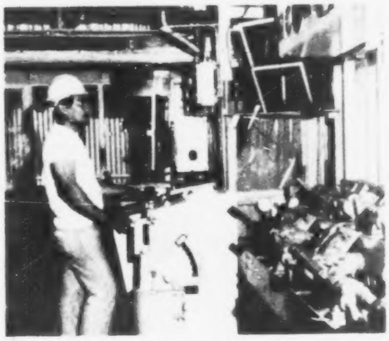
Continuing with dredging equipment was A. W. K. McDowell's paper "A review of 16 years' development of the underwater bucket wheel excavator and its current application to alluvial tin mining." The development and evolution of this equipment was detailed, pointing out the problems encountered and their solution, and the future potential for such units. Results achieved at two operations in Brazil were described in detail.

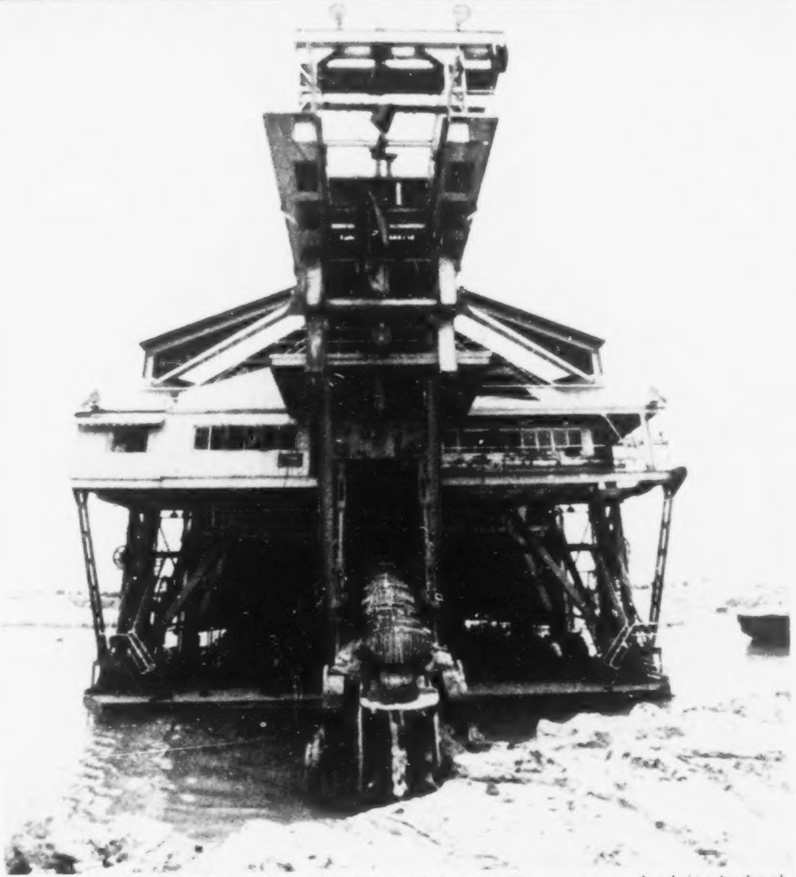
"Tin dredging operations at Berjuntai Tin Dredging Berhad, Selangor, West Malaysia" were presented by Lim Che Wan. This is one of the largest alluvial operations in Malaysia, with a current output of over 300 tons of concentrate per month. Current developments include the building of a new dredge and the modification of two others. One of the two dredges to be modified will be equipped with an experimental underwater bucket wheel.

Looking to a different, though still traditionally Malaysian, mining method, Hew See Tong examined "Investment in, and operation of, a gravel pump mine in typical dredged out land today." Over the last ten years there have been considerable changes in both investment requirements and mining methods for gravel pump mines. These have mainly been as a result of the need to operate in lower grade ground and rising operating costs. Typical gravel pump mines employ conventional open pit mine stripping techniques for overburden and monitoring for ore mining. As a result, capital requirements have increased vastly with earth moving equipment accounting for a high proportion of this capital.

"A regional approach to research on tin production" by A. H. Hassan dealt with problems faced by the tin mining industry in Indonesia, Malaysia, and Thailand, and their possible solutions. Many of the problems are common to all three countries because of similarities in deposits and extraction methods. Recog-

GRAVEL PUMP mining is being particularly hard hit by increasing production costs.





BASIC DREDGE design has changed little over the years. However, new dredging technology may increase operating depth onshore and enlarge the scope of offshore operations.

nizing this, the countries have formed the South East Asia Tin Research and Development Centre (SEATRAD).

Current research projects include the development of techniques for the exploration and mining of primary tin deposits, reducing costs by improving hydraulic mining techniques, development of drilling and sampling techniques for detrital tin deposits, and process control of treatment plant operations.

Turning specifically to the treatment side of the operation, W. P. Cross presented "Development of molded rubber plates for use in trommel screens." The current use of such screen plates for undersized material, after being discharged from the dredge buckets into the trommel screen, is the first time this locally-produced material has successfully been used in such applications since Peninsular Malaysian tin dredging commenced. Cross traced the development of a design which requires no reinforcing material and utilizes a clip-in principle.

The advantages claimed for molded rubber screen plates include their nonblinding properties, longer life than the conventional high carbon steel screen plates used previously, less maintenance, and ease of replacement. The application of such screens is on the increase.

The paper entitled "World tin consumption—present position and medium-term forecast," by U. Yahya and N. C. P. Hollands, moved the conference on to the second section covering consumption. Other papers in this section were: "Tinplate;" "Tin conservation in the canning industry;" "Solder;" "Canning;" "Tinplate can consumption potential in Asean;" "Material substitution and the demand for tin;" "Tin consumption meets the challenge from technological change;" "Recycling of packaging materials;" and "Consumption research benefits the tin industry."

J. C. Bowi opened the third section (Marketing—aspects and outlook) with a paper that considered the imbalance between physical tin supplies channelled through Penang and London against those marketed direct to consumers, "Tin marketing—polarization of interests between the producing and consuming element of the international tin industry." The four other papers in this section covered: "Market quotes and marketing practices;" "Establishment of a tin exchange in Malaysia;" "The use of the London Metal Exchange for hedging purposes;" and "The role of tin within the U. S. national defence stockpile."

Six papers were presented in the final section on investment, four covered production investment while two covered consumption investment. The first, by J. H. Forsyth, was "Problems affecting the financing of long-term development projects."

A paper prepared by members of Billiton International Metals BV examined "Considerations relating to investments in tin mining." The paper related particularly to offshore mining. The trend in tin mining is increasingly towards capital intensive, large-scale operations which, by their very nature, entail relatively high fixed costs and relatively low variable costs. For capital intensive investments, the rate at which the investment can be earned back is as important as the final profits, while for gravel pump mining—with relatively low capital investment—the governing criterion is more likely to be the profit attained.

The two remaining papers covering production investment were "An alternative method for projecting the evolution of the tin economy, with particular emphasis on investment," by H. Hashimoto, and "Some problems anticipated in developing a deep-seated alluvial tin deposit in Malaysia," by Thong Kean Sin. The latter covered a subject that will become a necessity in the near future if Malaysia's tin production is not to decline too sharply. The paper deals with the problems anticipated in mining a deep-seated alluvial deposit consisting of at least 76 meters (250 feet) of alluvium overlying soft mudstone. A possible mining method may be to operate a dredge in a deeply depressed paddock, employing pre-stripping of overburden ahead of the dredge.

The final two papers were, "Consumption investment in Japan" by K. Tanaka and "The tinplate industry in the European Economic Community—aspects of its future development." For further information about the conference and the papers, write to The Secretary, The International Tin Council, Haymarket House, 1 Oxendon Street, London SW1Y 4EQ, England, or to The Secretary, Steering Committee for the Fifth World Conference on Tin, Ministry of Primary Industries, Gurney Road, Kuala Lumpur, Malaysia. ■

The conventional sinter plant-blast furnace process currently accounts for 86 percent of all lead smelted in the western world. Economics of such a plant are examined through a western Canada feasibility project

Evaluating the economics of lead smelting

[illegible] F. C. King
Department of Energy, Mines,
and Resources
Ottawa, Canada and
George M. Meisel
Consulting Metallurgical Engineer
El Cerrito, California, United States

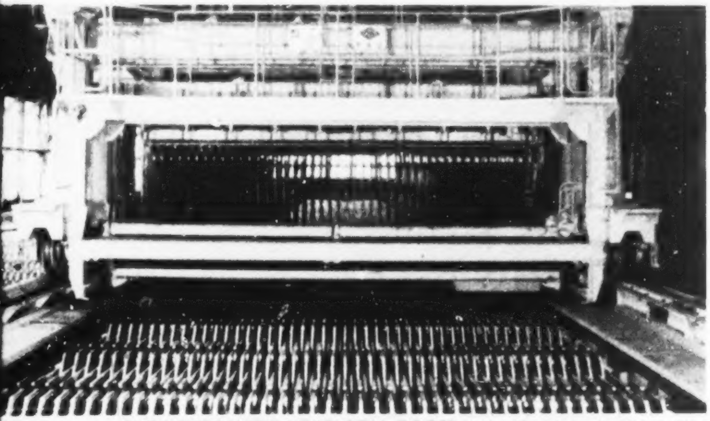
Mining companies with integrated smelting and refining activities tend to show greater stability and enjoy greater flexibility and control in marketing than do firms engaged only in mining. Integrated operations may also offer benefits through higher metal recoveries in mining and smelting and, in certain exceptional cases, an integrated approach may even be necessary to achieve acceptable overall metal recoveries. [illegible] article is intended as an example of how to evaluate a lead smelting and refining operation. [illegible] this an evaluation of future lead smelting and refining opportunities in Canada is presented. Capital and operating costs and revenues have been updated from a previous evaluation of this project, conducted in the fourth quarter of 1978.[1]

The smelting and refining operation is based on production of 100,000 metric tons of lead per year. The analysis is based on a site on the Pacific Ocean coast of British Columbia.

The concepts for this initial evaluation of the lead smelting and refining complex are based on the following criteria:

- Compatibility with the requirements for processing lead concentrates of an analysis expected in western Canada
- Meeting the constraints imposed by the environment and the logistics of the area
- Availability of capital and operating cost data from existing operations sufficiently similar to permit factoring for the proposed complex.

Best practicable current technology, for which reasonably reliable capital and operating costs are available, is the basis for the economic evaluation. It is acknowledged that current technology has limitations in terms of environmental compliance, although careful engineering has tranformed both sintering and blast furnace smelting from dirty operations to ones which, at a price, can approach the constraints of present environmental, safety, and health regulations. A greater problem is that of preventing lead from entering the plant environment from a fire refining operation. For this reason and the availability of relatively inexpensive hydro-electric power, an electrorefining operation is included in this study instead of fire refining.



ELECTYROLYTIC LEAD CELL ROOM at the Kamioka lead smelter of Mitsui Mining and Smelting Company Limited, Gifu Ken, Japan.

The operation conceived for this study is based upon well-proven technology, i.e., the conventional sinter plant/blast furnace process, which still accounts for 78 percent of the total number of plants and 86 percent of lead capacity in the western world,[2] plus electrorefining which is commercially well established in Japan and likely to supplant fire refining in new greenfield plants.[illegible] Concentrates are sintered, and the sinter reduced in a blast furnace. Lead bullion tapped from the blast furnace is cast into anodes and refined electrolytically.

A sulphuric acid plant with a bleaching stage is included to recover the sulphur dioxide from the sinter off-gas.

Order-of-magnitude capital and operating costs and revenues are estimated on this basis indicating that further investigation appears justified. Costs are estimated from data gathered from lead concentrate sintering and blast furnace smelting plants built in Missouri before 1970 and from two electrolytic refining circuits built in Japan in 1969 and 1975. P. J. Mackey[2] has referred to a smelter built in India in 1978, but the authors are unaware of any other world-scale primary smelters built since 1970. Costs of the Indian plant, even if available at the time of writing, would have been of limited use for a western Canada plant. The results reported here are as yet based on a generalized location on the Pacific Coast in the Kitimat/Prince Rupert area of British Columbia.

New Process Technology

While the study is based on conventional technology, some mention should be made of improved technology which may become incorporated in future plants. New lead processes under development include several based upon direct pyrometallurgical reduction of concentrates and some on chloride leaching. The direct reduction processes all have in common the elimination of sintering, although from the point of view of gas and dust containment, this advantage is lost to some extent in certain of the processes in which bullion and/or slag must be transferred to and treated in further stages.

Boliden Lead Process: In the Boliden lead process, which represents an early attempt at direct reduction and which has been commercially operated since 1963, dried concentrate and fluxes are fed into an electric furnace through the roof, producing a bullion containing 3 percent sulphur and a slag containing 4 percent lead. The lead is tapped periodically into one of two converters and blown to burn off the remaining sulphur. The high-lead slag is tapped into ladles from which it is poured into a slag fuming plant. Overall dust carry over in off-gases is reportedly about 42 percent of concentrate feed.[6] Refining is carried out in kettles. The process has never been adopted by other companies.

The consumption of energy in the Boliden direct reduction process is reported to be significantly less than traditional processes.

Top Blown Rotary Converter Process: The environmental disadvantage of having to transfer high sulphur bullion to a separate converting stage has led Boliden to adapt the top blown rotary converter to the smelting of lead concentrate with all stages carried out in one vessel.[7] As a result of this development, Boliden is planning a top blown rotary converter plant for the treatment of about 100,000 tons of high grade concentrate per year. This suggests that Boliden may be on the point of replacing its electrothermic direct reduction process. In the proposed new plant, oxygen enrichment of blast air will reduce off-gas volumes and, as with other top blown rotary converters, it is supposed that dusty off-gases will be contained by totally enclosing the furnace and tapping area, which will be vented to dust collection.

Three other examples of new lead extraction processes have been developed to various stages and may become available for commercial application within a few years. These processes appear to offer prospects for combining good metallurgical performance with comparatively inexpensive environmental control, i.e.:

Kivcet-CS Direct-Lead-Zinc Smelting Process: The Kivcet-CS direct lead smelting process is being developed under license from Russia by Klöckner-Humboldt-Deutz-Wedag (KHD). The trademark is the Russian acronym for "oxygen-flash smelting-cyclone-electrothermics," and CS stands for lead-zinc. However, a shaft furnace is used for the oxygen flash smelting of lead-zinc concentrates, different from the cyclone furnace used in the older and better known Kivcet-LZ process for copper-zinc concentrates.[8] Elimination of both the sintering and converting stages is achieved in this process. The concentrate is flash roasted and smelted in suspension using oxygen and the molten metal/metal oxide mixture then enters an electric furnace section adjoining the flash chamber, where lead and zinc oxides are reduced with coke. From results of pilot plant tests by the UNIICVETMET Institute at Ust-Kamenogorsk, Russia, KHD has designed industrial scale installations,[9] and is about to construct one in Bolivia.

QSL Direct Lead Smelting Process: The Queneau-Schuhmann-Lurgi process for direct smelting of lead concentrate is sponsored by St. Joe Minerals Corporation, Berzelius Metalhutten GmbH, and Lurgi Chemie & Huttentechnik GmbH. The principal economic and environmental benefits of this process are obtained by eliminating the sintering step. Fluxed concentrate pellets, powdered coal, and oxygen are fed to the reactor, and bullion, slag, and high strength SO_2 flue gas are discharged. The physical shape of the reactor is a cross between an SL/RN direct iron ore reduction kiln and a copper converter. This process has been developed to a large scale batch demonstration stage at Duisburg, West Germany. The results have been published in abstract form.[10]

Ferric Chloride Leach-Fused Salt Electrolysis Process: A ferric chloride leach and fused salt electrolysis process has been developed to a large scale continuous pilot stage at the U. S. Bureau of Mines Metallurgy Research Station, Reno, Nevada. The work is being sponsored as a joint government-industry effort by St. Joe Minerals Corporation, Amax Lead & Zinc Inc., and others. The encouraging results of prior stages of this work have been published by the U. S. Bureau of Mines.[11]

Imperial Smelting Process: A further alternative would involve the treatment of bulk or mixed lead/zinc concentrates by the Imperial Smelting Process (ISP). This process still requires sintering of the concentrates, but is in some ways a less far-reaching predecessor of the Kivcet-CS process. Given that Canadian lead concentrates are invariably prepared from lead/zinc ores, the ISP offers the potential for enhancing integrated mill/smelter recoveries further. The ISP should always be considered in the Canadian context because of its potential benefits in recoveries and shared infrastructure costs in an integrated operation.

Assumed Plant Criteria

In this exploratory review of plant economics there is no attempt at site comparison. The model is based on the Kitimat/Prince Rupert region at navigable tidewater, while recognizing that other physically suitable locations may exist in western Canada. Concentrates could be delivered by barge (as assumed here) or by rail from existing or future mines in British Columbia, the Yukon, or the Northwest Territories.

The size of any new primary smelter must satisfy certain basic requisites. It must be assured an adequate supply of concentrate and other operating materials, and be able to dispose of its metal products and byproducts, notably sulphuric acid, but is must also be large enough to achieve reasonable economies of scale. Potential concentrate supply may be enough to justify a much larger plant but it is thought that a nominally "minimum" world scale primary smelter of 100,000 tons capacity may be all that the markets might initially bear. However, the plant design must provide for later addition of a second blast furnace.

No attempt is made here to define the source(s) of concentrate for a western lead smelter. At present, the main sources of

Schematic materials balance in tons per year

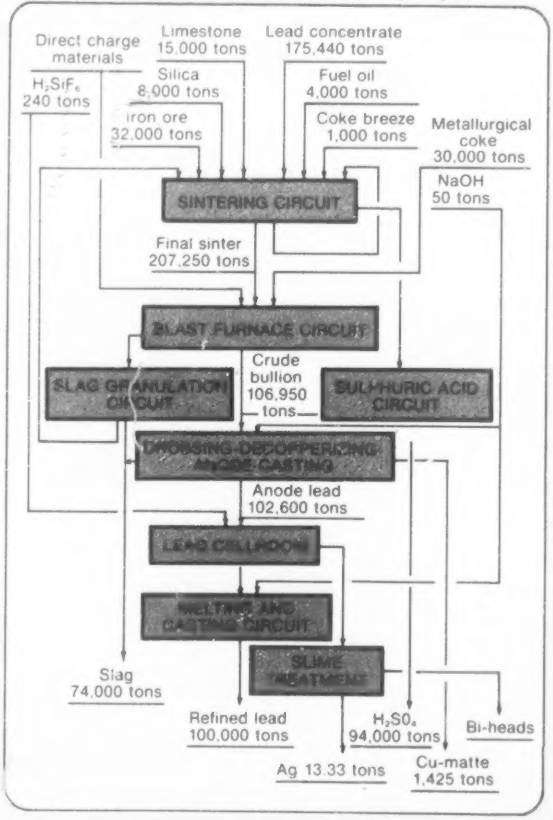


Table 1.

Content	Analysis	Recovery, percent
Lead	60 percent	95
Zinc	8 percent	0
Iron	7 percent	0
Silver	80 grams per metric ton	95
Copper	0.5 percent	65
Sulphur	18 percent	97

Table 2.
Order-of-magnitude capital costs

	Dollars
Receiving, proportioning, sintering	22,800,000
Blast furnace, slag granulation	11,300,000
Refining, melting, casting, shipping	26,000,000
Sulphuric acid (including bleaching stage)	16,200,000
Barge dock	5,100,000
General plant, yard, office facilities	12,000,000
Liquid effluent control	5,800,000
Subtotal	99,200,000
Contingency (20 percent)	19,800,000
Total constructed costs	119,000,000
Plus:	
Local sales and use taxes (waived)	—
Land acquisition (500 acres, nominal)	1,200,000
Mobile plant equipment	1,500,000
Personnel training and plant start-up	1,500,000
Spare parts inventory (3 percent of equipment)	1,900,000
Owner's administrative cost	3,700,000
Working capital from Table 3	16,200,000
Total other costs	26,000,000
Total capital costs	145,000,000

Table 3.
Working capital requirements

Item		Months required	Dollars
Operating materials and supplies	(from Table 6)	3	616,000
Fuel oil	(from Table 6)	3	531,000
Coke	(from Table 6)	3	1,335,000
Power	(from Table 6)	1	39,000
Maintenance materials	(from Table 6)	3	477,000
Payroll	(from Tables 4, 5)	1	689,000
Concentrates in storage and process	(from Table 9)	2	12,468,000
Total			16,155,000

Table 4.
Salaried staff and annual costs

Job	Number	Annual costs, dollars
Smelter manager	1	55,000
Production manager	1	43,000
Administration manager	1	34,000
Maintenance manager	1	43,000
Chief metallurgist	1	38,000
Chief engineer	1	38,000
Comptroller	1	38,000
Purchasing agent	1	34,000
Superintendant environmental safety and health	1	38,000
Superintendant quality control	1	38,000
Superintendant maintenance shop	1	38,000
Superintendant electrical and mechanical	2	76,000
Department superintendents	4	152,000
Security officer	1	26,000
Head nurse	1	24,000
Shift foreman	14	392,000
Maintenance foremen	4	112,000
Production engineers	3	90,000
Buyer, warehousemen, accountants	9	198,000
Plant engineers	3	90,000
Personnel administrators, miscellaneous	3	72,000
Analysts	4	96,000
Guard and scale house	8	160,000
Salaried subtotal	69	1,925,000
Burden 35 percent		674,000
		2,599,000

exported lead concentrate from western Canada are Cyprus Anvil Mining Corporation in the Yukon Territory and Pine Point Mines Ltd. in the Northwest Territories, both of which are presently tied to export sales contracts while Pine Point also supplies the Cominco plant at Trail, B.C. Over the longer term, other ore deposits will be developed in western Canada and adequate quantities of concentrate will become available.

The schematic materials balance shown in the figure is based on the assumption that the average analysis of the lead concentrates and the recoveries of their values contained are as shown in Table 1.

Dock and storage facilities are provided for both receiving concentrate and shipping sulphuric acid by barge. Barge delivery of concentrate is assumed not to require thawing facilities. However, thawing would be necessary if concentrate were transported by rail. Metal production is assumed to be shipped from the plant by truck, rail, or sea using existing facilities.

The charge proportioning operation for the sinter strand is assumed to be fully mechanized with weigh feeders equipped with modulating controls. Sintering utilizes an up-blast system with recirculation of weak sulphur dioxide gas from the discharge end of the sinter strand.

The hot zone of the blast furnace is water jacketed. A Roy tapper provides a continuous discharge of bullion and slag to a settler for separation.

Slag discharged from the settler is granulated and laundered to a sump from which it is transferred by bucket elevator to a load-out and haulage to the slag dump. A slag fuming furnace for zinc recovery is not considered in the present model. An electrothermic unit could be added for this purpose whenever the zinc market justifies the high power and coke requirements per ton of zinc recovered, i.e., 7,200 kilowatts per hour and 390 kilograms coke per ton of recovered zinc.[4]

Crude bullion is transferred from the settler to drossing kettles by ladle. Copper is recovered as matte from a small electrothermic or reverberatory dross furnace; the de-copperized bullion is cast into anodes for electrolytic refining. It is assumed that the matte contains 40 percent copper and 35 percent lead.

Electrolytic refining is carried out in a cell house equipped with automated "Jumbo" anode and cathode handling, and forced draft ventilation,[5,6] see photograph on page 48.

Dust and fume recovery points include the charge proportioning and charging, sintering and sinter handling, blast furnace charging and blast furnace tapper-settler, bullion drossing, and de-copperizing, anode casting, refined lead melting and casting, and other dry handling plant sections.

For control of liquid effluent, a two-stage lime precipitation and settling circuit is included for heavy metals removal and plant water reclamation from all gas scrubber bleeds and other effluent sources. In the present exploratory economic study no attempt is made to anticipate specific environmental regulations.

Evaporative cooling of off-gases in the dust collection train is accompanied by injection of pulverized limestone to prevent bag house fires which may result from pyrophoric dust. Dust from the bag house is returned to the sinter strand.

The acid plant, with a capacity of approximately 94,000 tons of sulphuric acid per year, employs two-stage conversion and absorption. A bleaching stage is included to make the otherwise "black" acid more easily marketable.

Capital Cost Estimate

The capital cost estimate summarized in Table 2 is expressed in fourth quarter 1980 Canadian dollars; it is nonspecific as to site, and is prepared by factoring and escalating the costs of existing respective plant circuits in Missouri and Japan. Thus the estimate is of order-of-magnitude, and a 20 percent allowance has been provided for contingencies as well. The costs of engineering and procurement have been pro-rated for each plant section. Originally prepared in U. S. dollars and yen, the estimates have been updated and adjusted to Canadian dollars and reflect current cost conditions in western Canada.

It is assumed that 36 months will be required for construction of the plant, followed by six months for tune-up to design capacity.

The allowance made for personnel training and plant start-up costs amounts to about one month's direct operating costs. The owner's administrative cost allowance, before and during construction, is based on actual Canadian plant experience, although it can vary greatly.

Operating Cost Estimate

Operating costs in fourth quarter 1980 Canadian dollars are developed by factoring the requirements for labor and the quantities of supplies and utilities for existing plants in Missouri and Japan. Costs are assigned to these quantities directly in Canadian dollars using unit costs applicable to the Kitimat area.

Total employment is 275, including 69 salaried and 206 hourly paid employees. Table 4 shows the distribution of salaried staff, salaries, and 35 percent allowance for payroll burdens and fringe benefits.

The distribution of hourly paid personnel and annual costs for each plant section is shown in Table 5. Estimated average wage costs of $9.42 per hour for smelter workers and $10.48 for maintenance workers are based on 40 hours per week and 52 weeks per year: this amounts to $19,600 and $21,800 per man-year respectively. After adding a further 7.5 percent overtime allowance and 25 percent for payroll burdens and fringe benefits, the total annual costs per person become $26,338 and $29,294.

Annual quantities of operating supplies and utilities, together with unit costs, and total annual costs for 100 percent plant capacity, are shown in Table 6. Where applicable, the unit costs include freight to the Kitimat area.

Table 7 is a summary of all operating costs, recapitulating the rounded-off totals of operating supplies and utilities, labor costs, maintenance supplies, plus allowances for property tax and insurance, all in constant end-of-1980 dollars. Costs are also shown for the first year of production, in which it is assumed that 95 percent capacity is achieved by the end of six months giving an average first year production of 72.5 percent, and for subsequent years during which an average 95 percent utilization is assumed.

Table 5.
Hourly paid personnel

Labor rates	Dollars Operators	 Maintenance
Average hourly wage rates	9.42	10.48
Average man-year wage (2,080 hours)	19,600	21,800
Overtime (7.5 percent)	1,470	1,635
Subtotal	21,070	23,435
Burden and fringes 25 percent	5,268	5,859
	26,338	29,294
Manning distribution		
Plant sections	**Persons**	**Annual costs (dolars)**
Materials handling, sinter, acid	40	
Blast furnace, slag handling	24	
Dross, de-copper, de-tinning	16	
Cellroom, melt, cast, ship	28	
Yard, change house, etc.	16	
Subtotal operating labor	124	3,266,000
Maintenance and shop labor	82	2,402,000
Total	206	5,668,000

Return on Investment

In this conceptual stage, where the feasibility of an additional lead smelter in western Canada is being analyzed, it is intended to present only a general indication of its rate of return. More detailed analysis will be necessary when more

Table 6.
Operating supplies and utilities (at 100 percent capacity)

Item	Kilogram per metric ton of lead	Annual quantity (metric ton per year)	Unit cost (delivered) (dollars per metric ton)	Annual costs (dollars)
Sinter charge flux:				
Iron ore	320	32,000	35	1,120,000
Silica	80	8,000	12	96,000
Limestone	150	15,000	30	450,000
Subtotal				1,666,000
Blast furnace flue treatment:				
Limestone fines	10	1,000	30	30,000
Drossing:				
Soda ash	16	1,600	248	397,000
Sulphur	10	1,000	100	100,000
Subtotal				497,000
Anode and pig cast:				
Caustic soda	0.5	50	840	42,000
Refining:				
H_2SiF_6 (25 percent)	2.4	240	175	42,000
Glue	0.45	45	2,310	104,000
Subtotal				146,000
Liquid effluent control:				
Lime	5	500	165	83,000
Total operating supplies				2,464,000
Fuel oil:				
Sinter (high S)	40	4,000		
Blast furnace	80	8,000		
Anode and pig cast	12.8	1,280		
Subtotal, fuel oil		13,280	1,690	2,125,000
Coke:				
Lump, blast furnace	300	30,000	175	5,250,000
Breeze, sinter strand	10	1,000	90	90,000
	kilowatt hour per metric ton	megawatt hours	cents per kilowatt hour	
Power:				
Dross furnace	85	8,500	1.64	
Refining	125	12,500	1.64	
Services	75	7,500	1.64	
Subtotal power	285	28,500		467,000
Total, fuel and power				7,932,000
Maintenance supplies (3 percent of equipment and piping)				1,909,000
Total operating supplies				12,305,000

Table 7.
Operating costs at various plant operating rates*

	Annual costs, percent dollars 100 percent capacity	 95 percent capacity
Operating materials and supplies	2,464,000	2,341,000
Fuel and power	7,932,000	7,535,000
Maintenance supplies	1,909,000	1,909,000
Salaries, wages, benefits	8,267,000	8,267,000
Property tax, insurance (1.5 percent of constructed cost)	1,785,000	1,785,000
Total operating costs	22,357,000	21,837,000

*Note: Employment costs, taxes, and insurance are not pro-rated.

precise information is available on capital and operating costs at a specific site, on corporate structure, and on general, administrative, and sales expenses.

Smelter revenues are estimated on an average of smelter schedules applying in the European Common Market and Japan. The proposed smelter will compete with the existing lead smelters in those two areas for lead concentrates from western Canada. Generally, smelter schedules provide for payment for the recoverable values in the concentrates at prevailing price levels, reduced by certain deductions, treatment charges, and penalties for impurities in troublesome quantities. The smelter schedules generally include formulae tying the treatment charges to the price of lead and/or the cost of energy and labor. While details of individual deductions and/or treatment charges vary from one smelter schedule to another, there is little difference in a normal competitive market in the net return to the smelter or to the mine from which it buys the concentrates.

Table 8.
Estimated return on original investment (based on end October 1980 costs and revenues)

Capital cost, from Table 2 in Canadian dollars		145,000,000
Revenues at 95,000 tons per year average output	**Canadian dollars per ton of concentrate**	**Canadian dollars per year**
Smelting charge (end 1978 Europe-Japan avgerage) (United States dollars) 85	100.00	
Wage escalation, 0.6 factor	7.20	
Fuel escalation, 0.3 factor	31.15	
Lead price escalation at (United States dollars) 0.45 per pound	0	
Subtotal, smelting charge, end 1980	138.35	
Ocean freight saving (Europe or Japan, average)	32.55	
Refining and marketing charge (Europe or Japan average) 1,254 pound lead payable per ton concentrate at (United States dollars) 0.045	66.39	
Values recovered without payment to mine		
Lead, 95 percent recovery at 30 kilograms per ton minimum deduction	0	
Silver, 50 grams per ton concentrate at 95 percent recovery	34.04	
Copper, 0.5 percent at 6 percent recovery	4.79	
Sulphuric acid, 0.54 ton per ton concentrate	5.40	
Total revenue, 166,670 tons concentrate per year	281.52	46,900,000
Total operating cost, from Table 7		21,800,000
Depreciation, 5 percent of construction cost, from Table 2		5,900,000
Operating profit		19,200,000
Estimated rate of return, before general/administrative and sales expense and before cost of interest and income tax		13.2 percent

Table 9.
Cost of concentrates (per ton)

	Dollars
Lead, 95 percent recovery at 30 kilograms per ton minimum deduction, 125,416 payable per ton	664.62
Silver, 30 grams payable per ton	21.50
Subtotal	686.12
Smelting charge, from Table 8	138.35
Ocean freight saving, from Table 8	32.55
Refining and marketing charge, from Table 8	66.39
Net payment to mine per ton	448.83

Plant revenues are based on an average 95 percent of capacity. Metal prices have been highly volatile during the past two years. However, the net effect on smelter revenues from the increased silver price is outweighed by the reduced lead price. The following net prices, freight-on-board smelter in Canadian dollars, were used in estimating revenues, as of end October 1980:

Lead:	$(Canada)0.53 per pound, corresponding to $(U.S.)0.45.
Silver:	$(Canada)22.29 per troy ounce, corresponding to $(U.S.)18.95.
Copper:	$(Canada)0.67 per pound contained in matte, reduced for the cost of converting and refining at $(U.S.)0.95 per pound cathode copper.
Sulphuric Acid:	$(Canada)10.00 per ton.

Results of the original study presented in April 1979 show that the return on the original investment would improve approximately 2.3 percent, if the proposed smelter were to become part of an integrated mining and smelting operation; such an integrated operation would benefit from federal and provincial tax provisions permitting part of smelter construction costs to be written off against mining profits.

A sensitivity analysis conducted as part of the April 1979 study indicates the approximate effect on the return on the original investment of variations in the lead price, treatment charges, energy cost, capital cost, and operating rate, as shown in Table 10.

Table 10.

Variation 5 percent +/−	**Approximate effect on return, percent +/−**
Lead price	1.4
Treatment charges	7.0
Energy cost	0.7
Capital cost	1.0
Operating rate	7.3

The authors are grateful for the valuable assistance provided by L. S. Gormely of Wright Engineers Ltd., H. A. Halvorson, and R. I. Burton, independent consulting engineers, all of Vancouver, British Columbia. Likewise, the advice and lead cellroom photograph contributed by Mitsui Mining and Smelting Company are appreciated. ■

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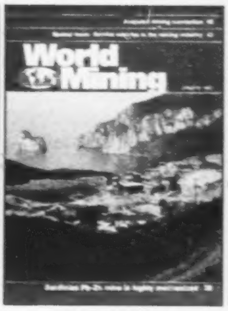

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World Mining

THE COVER

Concentrator plant at the Masua lead-zinc mine in southwest Sardinia. Samim has recently taken over management of all the base metal mines on the island; Masua is the most modern. It is a highly mechanized mine producing over 20,000 tons of zinc and 9,000 tons of lead each year, the major share of total Italian output. Although Masua is the current showpiece of the Samim group, development and modernization plans exist and are in progress for most of the group's other base metal mines (WORLD MINING, December 1980, page 7). *Photograph by John R. Chadwick.*

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Some 1,500 members of the Association of Mining, Metallurgical, and Geological Engineers of Mexico gathered to view mining equipment and hear 38 technical presentations

Acapulco mining convention and equipment show

By **Donald A. Fazour**
Managing Editor

Every two years, the Mexican mining industry takes a hard look at itself and examines what is new in mining technology and equipment. From October 25 to 29 last year, key mining engineers from this country convened in Acapulco, Guerrero for a technical convention held in coordination with a mining equipment exhibition.

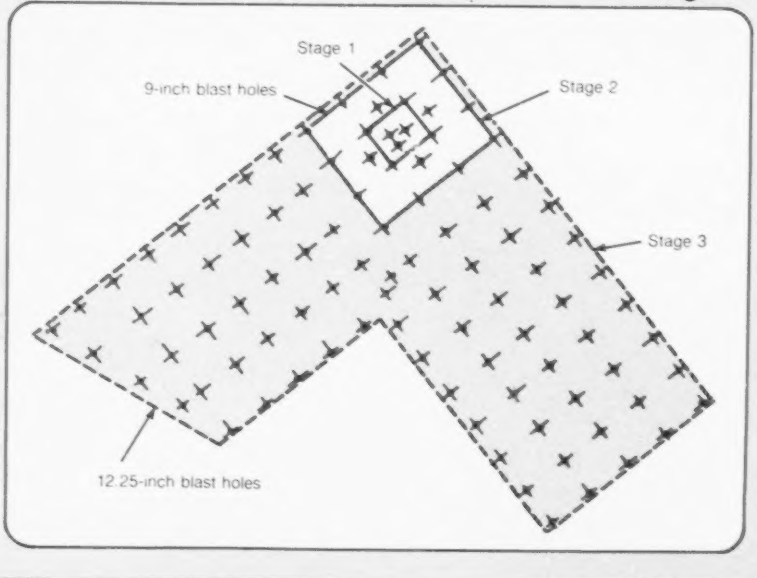
The mining industry of Mexico has long been an important contributor to the country's economy. It has been a growth industry as well. Mining is not growing fast enough, though, according to Ing. Fernando Hiriart, Undersecretary of Mines and Energy. In his opening remarks at the convention inauguration, Hiriart noted that while mining has grown by 48 percent in real terms over the past decade, industry in general has grown by 81 percent. Many old mines are expanding and new mines will start up in the coming years to increase this rate of growth.

While the lowered price of silver has been discouraging to many of the delegates attending the meeting, there was a general sense of optimism. Mexican mines for the most part are high grade. Engineers from the Mexican mines indicated that the emphasis at their operations is for greater mechanization and higher utilization of existing equipment. As the mines mechanize, in addition to allowing the companies to cope with the lower metals prices, lower grade material becomes ore.

Modelling Huge Copper Deposit

Some of the most important mines in Mexico have operated for scores of years. The Cananea mine, currently operated by Compañía Minera de Cananea S. A., has been in operation since 1399 and is still the largest known copper deposit in Mexico. For years, Cananea has been the largest copper mine in the country, but as La Caridad in the same state, Sonora, approaches capacity, Cananea will become the second largest mine—Cananea mines some 35,000 tons of ore per day, and La Caridad will mine on the order of 75,000 tons per day.

Cananea pillar blasting plan **Figure 1**



In one of three papers focusing on Cananea presented at Acapulco, Ramón Ayala and Daniel Chávez reported on a three-dimensional mathematical model of the Cananea ore deposit and described applications of this model. Before any modelling for any deposit can be started, a structured data base is needed. Cananea has, because of its long history, a substantial data base, but a great deal of work was required to structure this.

Geologists at Cananea had to catalog information on 5,183 drill holes, representing 425,000 meters (1,390,000 feet) of coring. Information from these cores was entered on 406,000 computer cards.

Because of the magnitude of the data base, a secondary data base for use with the model was created on the basis of composite information for 10-meter (33-foot) maximum increments of core information. Exact size of each increment was determined on the basis of geological criteria such as rock type, mineralization, etc.

The structure of the model consists of a matrix of equal-sized prisms. Each prism has a 25 by 25-meter (82 by 92-foot) horizontal surface dimension and a 15-meter (49-foot) height. Each prism is coded for rock type, mineralization, copper and molybdenum assays, and the value of variance for use in geostatistical analyses. The size of the modelled deposit is 6,000 by 6,000 meters (19,600 by 19,600 feet) to a depth of 1,200 meters (3,900 feet). The model is used for:

- Determining the distribution and classification of rock types
- Localizing geostructural elements
- Calculating reserves for different cut-off grades
- Geostatistical analyses
- Mine design
- Economic evaluations.

One special considereation in establishing the model is the effect on the deposit resulting from hollow or backfilled underground workings from past operations. A special program to account for partially mined, totally mined, or backfilled workings was developed to address this consideration.

Caving a Pillar for Safety

Quite apart from this mathematical modelling, old workings at Cananea are a major consideration in current open pit operations. This was the topic of a paper presented by José González, mine superintendent at Cananea. Open pit mining in Cananea began in 1944; underground operations, which began in 1899, terminated in 1960. Some of the past underground workings are now encompassed by the planned final pit limits.

González reviewed one particularly difficult safety problem that will be created when the mining level nears one of the larger open stopes, and explained how Cananea was confronting the problem. The stope, called 2-62, is located in the central portion of the "Colorada-Veta" open pit (See WORLD MINING September 1978, pages 64-70). The open space is 400,000 cubic meters in size and would require 680,000 tons of material to fill.

Through review of past data, rock mechanics studies, and careful evaluation of equipment weight and usage, it was determined that until the floor of the pit reached within 30 meters (98 feet) of the roof of this stope, operations in the pit could proceed safely. This dimension is equal to the width of the stope and equal to two benches in the open pit operation.

Once operations reach this level, a three-stage plan to cave the pillar above the stope is envisaged. First, an 8-meter (26-foot) diameter slot will be opened with seven 9-inch diameter drill holes, which will be blasted. The location of this slot is at the vertex of the stope (see Figure 1). The second stage will involve drilling 16 more holes and expanding the corner slot to 18.5 by 18.5 meters (60 by 60 feet). The third and final stage involves blasting the entire pillar and allowing it to cave into the stope. For this stage, a total of 75, 12.25-inch blastholes will be drilled. The shape of the stope and plan for caving it are illustrated in Figure 1.

Recovering Taxco Pillars

Cananea is not the only mine in Mexico faced with difficulties arising from past operations. At the Guerrero mine operated by the Taxco Division of Industrial Minera México S. A., some 416,267 tons of material grading 5.3 ounces silver per ton, 2.56 percent zinc, and 1.58 percent lead has been left in pillars within the mine stopes. This ore can only be recovered by backfilling the stopes, and this could be costly.

Engineers from Industrial Minera México have been studying this problem and seeking an economical way to refill the stopes and recover the ore. The studies that have been carried out were described in a paper presented by Gabriel Zendejas and Carlos Silva. The studies were based on using pneumatically fed dry tailings or sand to refill as mining of the pillars progressed.

Mining in the past has been through shrinkage stoping. The proposed recovery system of remaining ore envisions a 360-meter (1,180-foot) long by 3.9-meter (13-foot) wide operation. A concrete floor would be installed at the base of the proposed operations, through a depth of some 170 meters (560 feet), from level 1 to level 5. Two 1.8-meter (6-foot) diameter raises would be bored about 100 meters (330 feet) from either end of the operation from level 1 to level 5, to be used as ore passes to level 5, where haulage facilities exist. Two existing manways, on the north and south ends of the operation, would be rehabilitated. A 6-foot (1.8-meter) diameter raise would be bored from surface to level 1 for delivery of dry tailings or sands to the pneumatic injector. An 11-inch (280-millimeter) pilot hole would be drilled for an 8-inch (200-millimeter) pneumatic line to feed the fill material into the stope. Haulage within the stope would be by a 2-cubic yard (1.5-cubic meter) captive load-haul-dump unit. The proposed scheme is shown in Figure 2.

A financial analysis of the proposed scheme showed a 57.7 percent profit based on the value of a ton of the ore at current prices. Total cost per ton including mining, milling, indirect costs, and depreciation would be about $23.50.

New Peñoles Properties

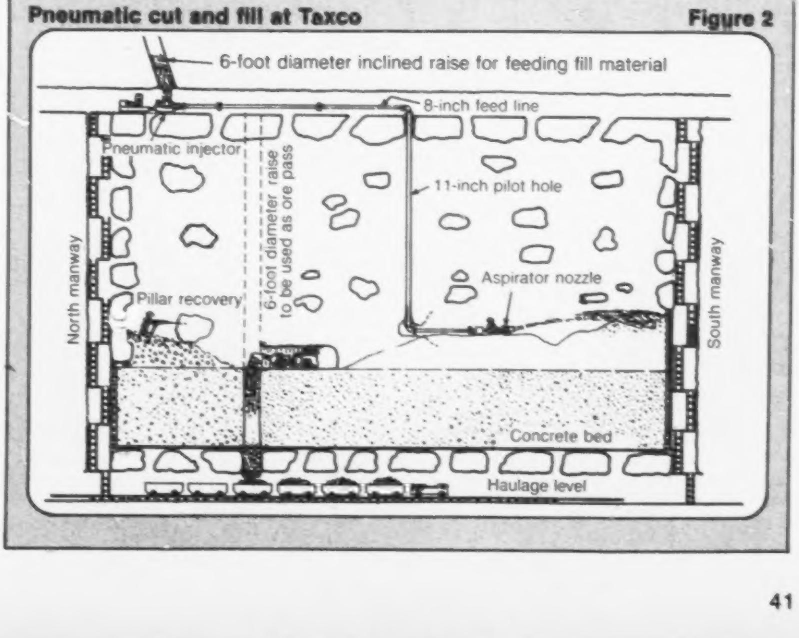
Five separate papers by staff members of Servicios Industriales Peñoles S. A. de C. V. showed how active this company has been in prospecting for future mining operations. The most advanced project described was the La Minita property in southwest Michoacán. Exploration to date on the property comprises 5,960 meters (1,950 feet) of drilling in some 78 exploration holes. Reserves are estimated at 6,400,000 tons of ore grading 2.3 ounces silver, 0.23 percent lead, and 1.27 percent zinc, and 58.79 percent barium carbonate and barium sulphate per ton.

The proposed operation for which feasibility studies are complete would include a 2,000-ton-per-day open pit operation with a 1.68 stripping ratio and a 52° pit wall slope. Laboratory and pilot plant metallurgical testing has been completed and a preliminary design for a 2,000-ton-per-day mill completed. Two papers on this operation were presented: one on plant design by Carlos Gómez and Fernando Grajales; one on pit optimization by Victor de la Garza, José Gaytán, Fernando Grajales, and José Olmos.

Another important Peñoles discovery is the Gohico silver-zinc-lead deposit some 30 miles (48 kilometers) north of Alamos in the northern state of Sonora. This deposit was dealt with in two presentations as well: the geology of the deposit was discussed by Luis Calientes; mine planning by Ignacio Martínez and Fernando Grajales.

Gohico has proven and probable reserves of 801,000 tons grading 4.7 ounces silver, 9.22 percent zinc, and 0.45

Pneumatic cut and fill at Taxco **Figure 2**



percent lead per ton. A 500-ton-per-day underground operation is planned with a projected start-up in April of this year. The mine will have a life of some five years at a mining rate of 500 tons per day. Mining and milling costs are expected to be $23.50 per ton, including direct and indirect costs. Even at today's low prices, Gohico should be a very profitable operation for Peñoles.

The final Peñoles property discussed by Javier García, Luis Novelo, and Juan Pérez, was El Rey de la Plata, a property that is undergoing extensive evaluation by Peñoles, but one which is not as far along in development as Gohico and La Minita. The paper that they presented discussed the general geology of the deposit and district where it is located, in the north-central part of the state of Guerrero.

The mine would consist of two separate deposits, El Rey de la Plata itself and the Tehuixtla deposit. Total estimated reserves to date are 1,700,000 tons grading 8.8 ounces silver, 1.7 percent lead, and 7.8 percent zinc per ton. There is still much exploration to be done on this property to verify and test for further reserves, the authors reported.

Huge Pipeline Project

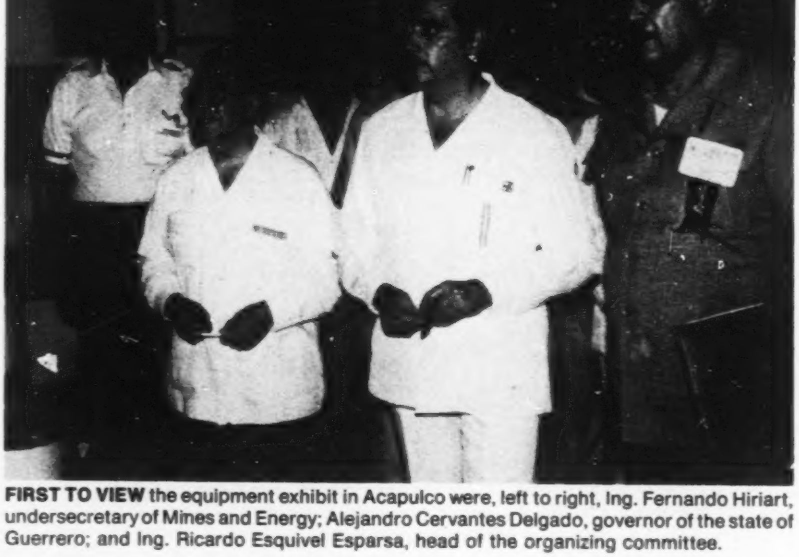
One of the most interesting papers at the convention was presented by Raúl Morales of Altos Hornos de México S. A. The paper described one of the largest slurry pipeline projects in the world, the 239-mile (384-kilometer) iron ore concentrate line that will carry concentrates for pelletizing from the La Perla and Hercules mines to the plant in Montclova through the states of Chihuahua and Coahuila. Table 1 shows the relative size of the new project to the other large slurry pipelines in the world.

Total cost of the pipeline will be $76,000,000 and the line should be operational late this year. Slurried iron ore will be transported at 60 to 70 percent solids through a two-stage system. The first stage begins with two 1,250-horsepower pumps at La Perla. The slurried concentrate will be pumped to Hercules, 55 miles (89 kilometers) away, at a rate of 202 tons per hour through an 8-inch (200-millimeter) diameter pipeline.

La Perla concentrate will be mixed with slurried concentrate from Hercules at this point. The combined concentrates will be pumped using three electric 1,500 horsepower pumps at a rate of 606 tons per hour through a 14-inch (355-millimeter) diameter pipeline to a third and final pumping station in the desert. The line from Hercules feeds directly into the pumping station. The desert pumping station comprises three 1,500 horsepower Diesel-powered pumps. Distance from Hercules to the pelletizing plant in Montclova is 184 miles (296 kilometers).

Table 1
Largest slurry pipelines of the world

Project	Miles	Metric tons per year	Pipe diameter (inches)	Start up	Material slurried
Black Mesa Arizona, United States	275	5,000,000	18	1968	coal
Samarco Brazil	248	12,000,000	20	1977	iron ore
La Perla Mexico	239	4,500,000	8/14	1982	iron ore



FIRST TO VIEW the equipment exhibit in Acapulco were, left to right, Ing. Fernando Hiriart, undersecretary of Mines and Energy; Alejandro Cervantes Delgado, governor of the state of Guerrero; and Ing. Ricardo Esquivel Esparsa, head of the organizing committee.

The above reviewed papers are but a few of many excellent and practical presentations heard by the Acapulco delegates. A large number of papers were concerned with geological studies conducted throughout Mexico. One paper described one of the first uranium occurrences being examined in the state of Sonora in northern Mexico. There were excellent mineral processing papers as well. Metallurgists from Industrial Minera México reported on research conducted on lead-copper differential flotation. Engineers from Compañía Real del Monte y Pachuca S. A. described tests of theirs that used lamella thickeners for counter-current decantation of silver-gold leach slurry. All papers were made available to the delegates in a 1,445-page hardbound proceedings volume.

Well-Paced Program

Technical sessions were scheduled from 10:00 a.m. to 2:00 p.m. This allowed delegates ample time for personal discussions and for viewing the equipment exhibited at the Acapulco convention center. Most all equipment manufacturers from Mexico, the United States, and Europe were present at the show, and engineers had the opportunity to see most of the 15,000-square meter (161,500-square foot) exhibit.

Manufacturers, who can frequently gauge potential growth of an industry they serve, were enthusiastic about Mexico. As important to the growth of the industry as new mines are those mines that are being expanded. The newsletter on pages 7 and 9 of this issue clearly documents the magnitude of the expansions underway in Mexico.

Because it is a government policy to favor domestically produced products over those imported from abroad, more and more companies are either in the process of or are considering establishing manufacturing facilities in Mexico.

The Acapulco show has been growing each year and the next convention, to be held in late fall, 1983, should be larger than ever. Although specifically aimed at Mexican mining engineers, it should be well worth attending by non-Mexican mining professionals as well. ■

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World Mining

FEBRUARY 1982

INTERNATIONAL GUIDE TO BLASTHOLE DRILLS

FEBRUARY 1982
VOLUME 35, NO. 2

World Mining

THE COVER

Blasthole drilling in a northern open pit mine. There are many trends in blasthole drilling today, such as increased demand for angle drilling, new markets for electric drills, and a keener interest in long bit life. John Chadwick has assembled the facts in a special report.

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Cobalt Today and Tomorrow 48

A generally optimistic view prevailed at a recent international cobalt conference, held in Brussels, Belgium. John Chadwick was there, and has filed this report

World Mining Congress 53

The 11th edition of this uniquely important convention will be held in Belgrade, Yugoslavia in just a few short months. George Argall, who is on the Congress' Organizing Committee, has all the details in a pre-Congress outline

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The mood was one of cautious optimism. As ever, when cobalt is discussed, Zaire and Zambia were the focus of attention. There was great diversity of opinion concerning the potential of cobalt production from undersea nodules

Cobalt today—and its future recovery and use

By **John R. Chadwick**
Associate Editor

Despite the weak cobalt market that has prevailed for almost the last two years, the "International Conference on Cobalt—Metallurgy and Uses" held in Brussels, Belgium, in mid-November 1981 attracted some 300 delegates from almost 30 countries. The conference brought together producers and users and was significant for the generally optimistic view of the future of the cobalt market held by a large number of those attending. This optimism carried over, in some people's minds, to the copper market.

Appropriately, the first session was opened by a paper from the leading producer country, Zaire. This session was devoted to cobalt resources and the questions of supply and demand. Lukusa Muengula, of Sozacom, presented "The Cobalt Future in the Competitive Strategy." Muengula predicted that for the next five years, Zairean production of cobalt would rise at 4 percent per year; production in 1980 was 14,500,000 metric tons of metal. This increased production is to come from previously undeveloped reserves and the redevelopment of old mining areas.

Muengula quoted a U.S. Bureau of Mines figure for an expected 3.5 percent growth rate in United States cobalt consumption. It was later pointed out by one of the delegates that the U.S. Bureau of Mines had subsequently stated that permanent substitution of cobalt in the United States now amounted to a figure of almost 910,000 kilograms (2,000,000 pounds). In addition, Muengula quoted a growth rate of 3.3 percent for cobalt consumption in the rest of the western world.

He highlighted the need for stabilizing the producer price and urged for better cooperation between cobalt users and producers. On this point, he informed the conference that on the previous day, November 9, 1981, the cobalt producers, in a meeting in Brussels, had agreed to set up a center for the development of cobalt. (see World Mining, January 1981, page 67). The aims of the center would include promoting the use of the metal and providing technical assistance to the end users.

The second paper, entitled "Cobalt Resources: Reserves and Availability," was presented by P. Scheidweiler of Société Générale des Minerais. He began by discussing the current supply situation; some 95 percent of western world cobalt production comes, as a by-product to copper production, from Zaire and Zambia, or as a by-product from nickel mining elsewhere in the world; the world's only primary cobalt producing mine is the Bou Azzer in Morocco (see World Mining, March 1980, page 7).

The known, mineable reserves of cobalt in the world today amount to between 3,000,000 and 5,000,000 tons. In addition, there are a further 4,000,000 to 5,000,000 tons classified as potential reserves. Interestingly, the largest tonnage is to be found in Cuba, 800,000 tons, but this cobalt is in lateritic deposits and cannot be extracted economically as yet. Similarly, large reserves in Indonesia are also uneconomic to mine at present. Zaire, the number one producer, has reserves of 450,000 tons.

At present, less than 25 percent of the mineable reserves are being exploited; another 25 percent of these reserves are under study; and over 50 percent of the mineable reserves are receiving no attention whatsoever. At present, of the 800,000 tons of mineable reserves that are being mined, 70 percent are in central Africa. Of the 900,000 tons of mineable reserves that are under study, only 40 percent are in central Africa. Further, pointing to even less dependence on this area of the world, of the remaining 2,200,000 tons of mineable reserves, only 15 percent are in central Africa.

However, breaking the mineable reserves up by quality presents another interesting picture. High grade reserves amount to 400,000 tons and are all in central Africa; medium grade reserves total 950,000 tons, of which 47 percent are in central Africa; finally, the largest tonnage, 2,550,000 tons, is in low grade reserves, of which only 15 percent are to be found in central Africa. Dividing the total mineable reserves by annual production gives a reserves life of 80 years. Dividing high grade reserves gives a life of just 27 years.

Scheidweiler then went on to discuss the implications of undersea mining. Identified cobalt resources undersea amount to 500,000,000 tons, while on land they amount to just 10,000,000

Table 1.
Substitution and growth potential for cobalt by use

Use	Substitution Potential Short Run	Long Run	Growth Potential
Superalloys	Minimal	Moderate	Moderate; aerospace slowdown, new fabrication methods
Magnetic Alloys	Major	Major	Low, unless markets develop for cobalt-rare earth magnets
Carbides and or Hard Metals	Minimal	Minimal	Moderate; strong energy-related demands partially offset by recycling and new products
Tool Steels	Moderate	Moderate	Low
Hardfacing	Moderate	Moderate	Low
Catalysts	Minimal	Minimal	Good; may be offset by recycling
Other Chemicals	Moderate	Moderate	Moderate

tons. However, many factors still militate against seabed mining, including the vast investment sums that will be required, and the fact that the Law of the Sea has still to be agreed upon. There has been no significant production from this source to date. However, there will come a time, when the profitable reserves have been exhausted, when the choice has to be made between developing the marginal land reserves or commencing seabed mining.

In discussing the cobalt pipeline, Scheidweiler pointed out that to achieve security of supply, a working pipeline should contain about 20,000 tons of cobalt, the pipeline being the amount of cobalt in transit, in various situations, between the producer and the user. He went on to discuss stockpiles and differentiated between the United States stockpile, which is truly strategic, with military requirements taking first priority, and the Japanese and European stockpiles, which are established mainly for economic reasons. He pointed out that the current level of the GSA stockpile is about 20,000 tons but that the goal for the future is to raise this level to 37,000 tons. In conclusion, Scheidweiler stated, "cobalt still looks promising."

J.C. Agarwal, of Charles River Associates, presented "Role of Cobalt in the Industrial Society." He began by noting the 1980 world consumption of 22,000 tons. He went on to consider cobalt's uses, and reported that its high temperature characteristics were still the most important. No replacement is likely to be found for cobalt in the near future for such applications. In fact, when considering substitution in such uses, it is not price that is the determining factor, but availability. Oil industry usage in catalysts is also still on the increase, particularly in connection with sour gases and oil. Table 1 shows the predictions for substitution and growth potential of cobalt by use.

The ratio of the cobalt price to the copper price, which was 8 to 1 at one time, has now risen to 25 to 1, a great incentive to increase cobalt recoveries. On the subject of seabed nodules, Agarwal reported that the cobalt grade of these deposits ranged from 0.1 to 0.25 percent. It is very difficult to recover cobalt from this source, he said. In fact, laboratory test work has only achieved recoveries of around 30 percent and in his opinion, 50-percent recoveries would be very optimistic. A 3,000,000-ton per year manganese plant based on seabed nodules could produce 3,600 tons of cobalt per year, but it would cost some $1,500,000,000 to set up with a further $250,000,000 to develop the technology. In his opinion, seabed mining is still 10 to 20 years away, and the latter is most probable.

However, Agarwal also concluded on a note of optimism, saying, "as long as the cobalt supply is assured, people will find new uses for the metal."

Cobalt Optimism

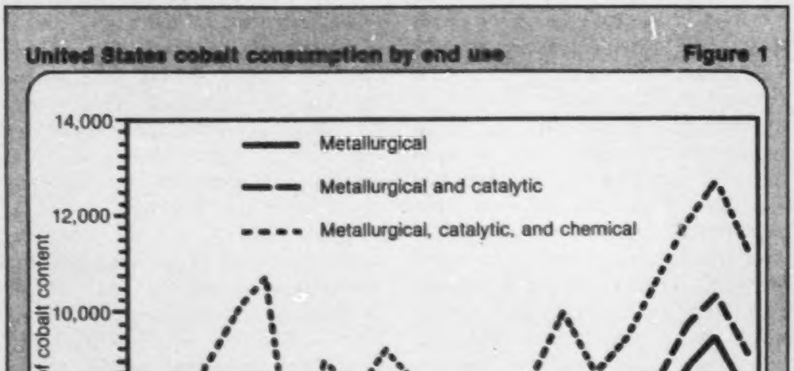
The final paper covering the overall cobalt market was, "Cobalt—a Critical Material?" by Jorn P. deLinde, a report on the cobalt aspect of an extensive research program into critical ferroalloys carried out by Chase Econometrics.

The year 1979 was not a good one for cobalt in the United States. Total consumption declined by more than 7 percent. Primary consumption fell even more as secondary recovery continued to advance. This malaise was caused by the tight supply situation and consequent sharp rise in price, spurring considerable substitution and conservation efforts by cobalt users. Preliminary information for 1980 indicated an 11 percent drop in total United States consumption. Figure 1 shows the prediction for future cobalt consumption in the United States. Peak consumption occurs in 1989, at almost 13,000 tons.

In discussing substitution and whether it is permanent or whether users will return to cobalt at lower prices, deLinde made the following, very interesting point. "There may be a fundamental difference between civilian and military markets in this respect. In civilian applications price, cost, and performance are always part of a trade-off, whereas the military generally wants the highest performance that is technically possible regardless of cost." The Chase forecast does assume that there will be "a fair degree of reversible substitution." Looking to total western world consumption, stronger advances are expected outside of the United States and Japan in the coming decade.

Considering the security of supply, there is no absolute shortage of reserves. The problem is that vast quantities of the reserves are situated in countries facing political or economic difficulties. About 2,000,000 tons of cobalt were classified as reserves by the U.S. Bureau of Mines in the 1980 edition of Mineral Facts and Problems. Of this total, almost 78 percent is located in Zaire and Zambia. Reserves outside of these countries are only the equivalent of 16 years demand at the 1974 level, while reserves including Zaire and Zambia total 73 years demand at this level. There are no significant cobalt deposits classified as reserves in the major industrialized countries at present.

When considering the fact that the majority of cobalt production is a byproduct of copper production, deLinde made the following observation. "We view copper as seriously underpriced rel-



United States cobalt consumption by end use **Figure 1**

ative to long-term costs as we enter the 1980's, and the lack of adequate growth in copper mine capacity is likely to produce a much tighter copper market by the mid-1980's than we are currently experiencing. The consequent sharp rise anticipated in copper prices serves to diminish production costs for cobalt through the mechanism of by-product credits."

The conclusion of the Chase Econometrics research is one of optimism for the cobalt user: "The underlying economics of cobalt supply in the 1980's look relatively favorable, particularly with regard to the expected increase in the profitability of associated copper mining."

Cobalt Extraction

Professor J. De Cuyper of the University of Louvain began the session on cobalt metallurgy by reviewing "Concentration of Cobalt Ores." He commenced with a look at the main cobalt ores being processed: cobalt in the form of sulphides, arsenides, sulpho-arsenides,and oxidized cobalt minerals. De Cuyper reviewed the various physical concentration techniques available for cobalt ores and gave details of the flowsheets of many of the cobalt concentrators around the world, including the Gecamines' plants in Zaire; the Zambian concentrators at Baluba, Rokana, and Chibuluma; the concentrator at the Bou Azzer mine; the Kilembe plant in Uganda; and concentrators in Finland and Japan. At the Bou Azzer concentrator, for instance, gravity methods are used on the cobalt arsenide ore to produce concentrate with a Co content ranging from 6.5 to 17.5 percent.

Concerning laterite ores and seabed nodules, De Cuyper does not see much potential for physical concentration techniques. Looking to the future, improvements in cobalt concentration are foreseen for the operations in Zaire and Morocco, through greater selectivity. Selective chelating agents, dealt with in a later paper, have great potential for improving future recoveries. The emphasis, up to now, has not been on improving cobalt recovery. This situation is likely to change in the future.

Reijo Anttonen presented, "How Outokumpu Beneficiates the Low Cobalt Contents of its Sulphide Copper Ores." Cobalt concentrates are produced by flotation at the Keretti and Vuonos mines. These cobaltiferous pyrite concentrates are further treated at the Kokkola cobalt plant. The head grades of the Keretti and Vuonos ores are 2.7 and 1.9 percent Cu, 0.6 and 1.1 percent Zn, and 0.23 and 0.12 percent Co, respectively. The cobalt concentrate from Keretti contains 0.7 percent Co, and from Vuonos 0.9 percent Co.

The cobalt carriers of the Keretti ore are pyrite (0.8 percent Co), cobalt-nickelpentlandite (33 percent Co), and pyrrhotite (0.1 percent Co). The Vuonos ore is geologically similar but there are only minor amounts of pyrite. In both ores the cobalt-nickelpentlandite occurs partly as extremely fine ex-solutions in pyrrhotite. Selective flotation is the method used, with on-stream analysis. A pilot cobalt flotation plant has been tested, but not with much success as yet. At Vuonos, cobalt scavenging has been introduced successfully. The recovery at this concentrator runs at 51 percent Co. Anttonen also discussed the influence of the degree of grind; trials of different reagents; the effect of process water circulation; and economic optimization of copper-cobalt separation.

Moving further along the cobalt production process, Doctor Claude Feneau, of Metallurgie Hoboken-Overpelt, discussed "Extractive Metallurgy of Cobalt." This was a review of many of the most important cobalt plants in the world and the various routes available for the production of finished cobalt.

Processes based on primary cobalt concentrate include roasting, leaching, and electro-winning in sulphate media. In the case of arsenical ores, leaching and electro-winning are carried out in chloride media. Secondary feeds, such as mixed cobalt-nickel sulphides, cobalt-nickel mattes, or alloys, are processed in different media, including sulphate, chloride or ammoniacal. Feneau also considered very specific processes for the treatment of slags, nodules, and spent catalysts, and commented that recycling of the latter will increase.

"Sumitomo's Cobalt Refining Process" was described by N. Ono. Sumitomo Metal Mining Co. Ltd. (SMM) operates a hydrometallurgical plant for nickel and cobalt recovery from their sulphide mixtures and hydroxide precipitates produced at the Niihama nickel refinery. The outline of the process is as follows:

1. Pressure leaching of the sulphide mixtures
2. Purification of the leached solution
3. Nickel and cobalt separation by solvent extraction
4. Gypsum production and ammonia recovery from ammonium sulphate solution from the solvent extraction process
5. Production of electrolytic nickel and cobalt from their respective chloride solutions by electro-winning
6. Recovery of chlorine gas from electro-winning and the production of hydrochloric acid

The plant produces 2,500 tons of electrolytic nickel and 1,500 tons of electrolytic cobalt, at full capacity, with some by-products such as nickel chloride, cobalt oxide, cobalt nitrate, and cobalt sulphate. The finished products contain 99.98 percent nickel and 99.94 percent cobalt, respectively. The major impurities in the electrolytic cobalt are 0.004 percent Cu, 0.005 percent Fe, 0.003 percent Zn, and 0.001 percent S.

Considering the world's major producer, Tshofu Shungu, of Gecamines, described "Recent Improvements in Metallurgical Processing at the Cobalt Granules Plant of Shituru." Here, improvement of the quality of the cobalt product has depended on improving the conditions of electrolysis and thermal refining. In electrolysis, Gecamines conducted research into the effect of pH, the influence of current density, and the effect of temperature. In the laboratory it was found that, the current efficiency initially increases with pH up to a value of 6.2. Then, however, it decreases with increasing pH. A higher pH produces a considerable increase in nickel and sulphur contamination.

Increasing current density results in a decrease of current efficiency. At a current density of about 220 amps per square meter (and a current of about 7,000 amps), the current efficiency is over 90 percent. The efficiency falls to about 80 percent when the current density is increased to 375 amps per square meter.

In the laboratory, higher temperatures of electrolysis result in improved current efficiencies and lower nickel and sulphur contamination. On moving to industrial scale tests, Gecamines had to change to sandblasted stainless steel blanks to successfully achieve the benefit of higher temperature electrolysis. Table 2 shows the improvement that was achieved by electrolysis at 80° C, compared with electrolysis at 60° C.

Gecamines examined three improvements: the quality of the reactives, the method of charging the furnace, and operation control, with a view to increasing the efficiency of thermal refining. The first step to control iron contamination by the reactives was to replace sand by CaF_2. This helped to increase both the fluidity of the slag and its desulphurizing capability. Also, silico-calcium was replaced by a better sorted and less oxidized product (silalcium). This allowed the sulphur content of this reactive to be reduced from 1,276 to 1,103 parts per million.

It was also found to be beneficial to replace rock lime with crushed lime and to inject it directly into the furnace bath, thereby further reducing iron contamination. With a view to improving sulphur contamination control, Gecamines will buy equipment to rapidly analyze sulphur contents.

The concentrates produced at the Bou Azzer mine in Morocco are sent to Savoie in France for further processing. This plant was described by F. Peyron in "A French Producer of Cobalt: Metaux Speciaux S.A." The concentrate received is first treated by roasting, to recover the arsenic as a high purity trioxide. Subsequent hydrometallurgical treatment of the calcine is as follows:

- Hydrochloric leaching in the presence of gaseous chlorine
- Recovery of dissolved gold
- Solution refining to recover Cu, Bi, Ag, Zn, Cd, Pb, Ni, and Fe
- Electrolytic production of metal from cobalt chloride
- Refining of spent electrolyte, yielding cobalt oxide, which is the basic source of by-products such as cobalt salts and oxides.

Although this process was specifically developed for the hydrometallurgical treatment of cobalt arsenides, it can be adapted to the treatment of sulpho-arsenides and other cobalt-bearing raw materials. For the electro-winning of the cobalt, cells and anode compartments made of plastic are used. The anode is made of graphite and the cathode of stainless steel. The current efficiency is around 90 percent, at a temperature of 60° C and with a cathode density of 350 amps per square meter.

"The Recovery of Cobalt from Laterite Ore" was discussed jointly by L.A. Goeller and C.D. Low of UOP Inc. Nickel laterite ores are a large and still largely undeveloped source of both cobalt and nickel, representing some 65 percent of cobalt reserves. Reductive roast-ammonia leach technology offers good recovery of both cobalt and nickel—70 percent of the cobalt and 90 percent of the nickel. The cost of the cobalt production is estimated to be in the neighborhood of $4.50 per kilogram ($2.00 per pound).

UOP's Nickel Extraction Process relies on the use of additives in the roast step to increase metal recovery from a wide range of ore types, including the more refractory saprolitic ores. The additives include various sulphur forms (gaseous and solid) and halides. Figure 2 shows the roast and leach sections of the UOP Process. The process and other alternatives were described in detail, including a good deal of information on operating and capital costs.

M. Bourahla, of Sonarem, Algeria, described laboratory work that had been carried out for the "Purification of Cobalt Chloride Solutions—The Winning of Very Pure Metal and its Characterization." Iron was removed from a chloride solution using solvent extraction, with M.I.B.C. Then ion exchange in a Dowex resin column was carried out to remove the nickel. Low intensity electrolysis was carried out to eliminate elements such as copper and lead, and then the main electrolysis was carried out to produce very pure cobalt. Ultimate purification was achieved by zone melting or thermal treatment.

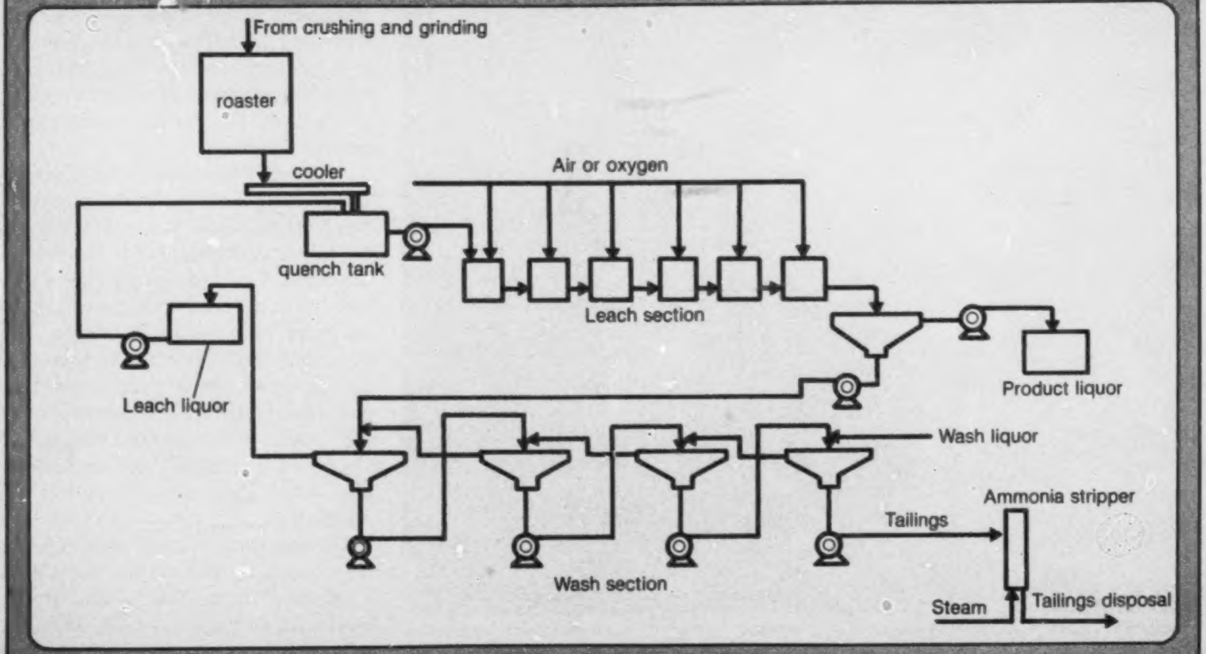
In "The Chemistry and Thermodynamics of a Hydrometallurgical Sulphite Route for the Recovery of Cobalt," D.C. McDonald, P.B. Linkson, and

Table 2.
Quality of cobalt obtained by electrolysis and from reference cell

Impurity content (parts per million)[1]	Co	Cu	S	Fe	Ni	Pb	Zn	Ca
Electrolysis at 60° C	98.9 percent	75	650	70	960	40	6,600	107
Reference cell at 60° C	95.8 percent	58	1,100	275	1,280	110	22,000	321

1. With exception of Co.

Roast and leach section, UOP process **Figure 2**



D.M. Nobbs, of the University of Sydney, Australia, discussed the recovery of cobalt sulphites from aqueous solutions by addition of sulphur dioxide and subsequent adjustment of pH. The effects of temperature and of the spectator ions, sulphate, nitrate, and chloride on precipitation of the cobalt sulphite were elucidated by a thermodynamic model for metal sulphite precipitation, with experimental determination of species in the solutions. The recovery of cobalt from solutions containing nickel and/or copper via routes involving sulphite salts was also covered.

D. Pearson of Warren Spring Laboratory, United Kingdom, closed the metallurgy session with "Recovery of Cobalt from Metallurgical Wastes." Some of the processes to recover cobalt from sludges and grindings were reviewed and a new laboratory process was described. In this, major metal values are dissolved in sulphuric acid and separated by precipitation and solvent extraction, using a newly-developed extractant. High purity metal is then electro-won. Data presented showed that costs range from $4,500 to $7,300 per ton of cobalt recovered.

A further 16 papers were presented on the uses of cobalt. There were also a series of poster sessions, with some papers of great interest to the cobalt producer. G. Rinelli and A.M. Marabini, from the CNR Laboratory, Italy, discussed the "Possibility of using Chelating Agents in the Flotation of Cobalt Minerals." The presentation included proposed applications for the concentration of refractory ores, as cobalt oxides and/or arsenides.

The "Recovery of Cobalt from Ocean Nodules and its Impact on the World Market" was covered by J.C. Agarwal, J.H.R. Black, and B.J. Reddy, of Charles River Associates. One ocean mining project achieving 80 percent cobalt yield could produce 6,000 tons of cobalt annually. This sort of operation could become important in the 1990's, provided that legal and technical problems are resolved. Five major consortia are involved in this research. If they were all to come on stream in the next decade, there could be 30,000 tons of cobalt for the market to absorb from this source. This would obviously drive the price down.

"A New Generation of American Cobalt—The Anschutz Madison Project" was described by Spisak of the Anschutz Mining Corp. To be on stream in early 1984, this project, centered in the old Missouri Lead Belt, will produce more than 9,000 tons of cobalt and 10,000 tons of nickel during its minimum 10-year life. A bulk sulphide beneficiation circuit is expected to achieve a cobalt recovery of 90 to 93 percent. Copper will also be produced at an annual rate of 15,000 tons.

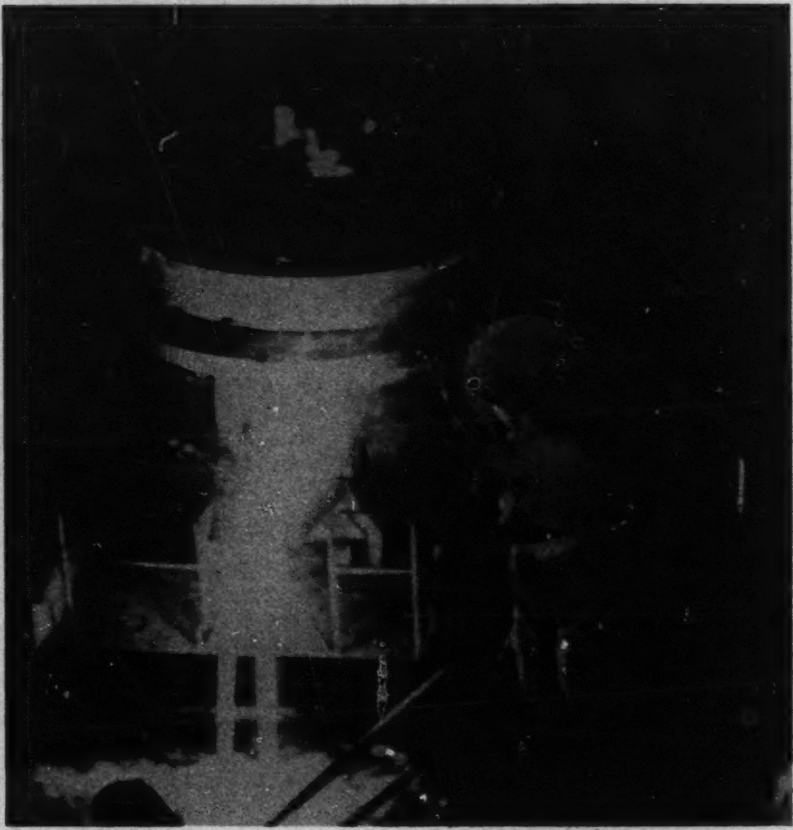
Cyanex CNX was described and its application considered in "Phosphine Chemicals—A New Era in Selective Extractants," by D.R. Burley of American Cyanamid. R.G. Reddy and G.W. Healy, of the United States, reported on "Studies on Removal of Cobalt from Liquid Copper Scrap under Fire Refining Conditions."

Members of the National Metallurgical Laboratory, India, covered "Recovery of Cobalt from Lateritic Nickel-Cobalt Ores with Special Reference to Sukinda Ultramafic Field." The nickeliferous laterite of this area is the only known potential source of nickel and cobalt in India. Reserves of approximately 98,000,000 tons of ore containing 0.8 percent Ni and 0.06 percent Co have been estimated around the Kansa area. Moreover, overburden removed in several major chrome mines in the area has been found to be lateritic in nature, containing 0.5 to 1.2 percent nickel and around 300 parts of cobalt per million.

A study of the Kamoto, Zaire, ores was presented by C. Ek, J. Frenay, and B. Lorea of the University of Liège, Belgium, in "Treatment of an Oxide Copper-Cobalt Ore." The oxide minerals, such as tenorite, malachite, pseudomalachite, and heterogenite, assay 2.2 percent Cu and 3.8 percent Co. Flotation tests were very disappointing, but leaching with sulphuric acid achieved recoveries up to 96 percent for copper and 90 percent for cobalt.

"Cobalt Extraction from Potential U.S. Resources Today and Tomorrow" was presented by B. Yarar of the Colorado School of Mines and L.J. Miller of Texasgulf. There are indications of a cobalt-bearing Permian shoreline extending from Texas to North Dakota. Further, shale beds in South Dakota show similar formation to deep sea nodules and strongly indicate the presence of cobalt along with 25-percent manganese. Other deposits as well as deep sea nodules and metallurgical wastes were also discussed.

The complete proceedings of this conference are available from the Centre d'Information des Metaux Non Ferreux, Boulevard de Berlaimont 12, 1000 Brussells, Belgium. ■



MOLTEN COBALT metal is tapped out of an electric furnace into a water bath, for cooling and granulation. More than half of the cobalt produced in the world is melted this way.

After THOUGHTS

With Southwestern United States copper mines reducing capacity or halting operations, everyone is wondering about the future of one of the most important nonferrous metals markets in the world. The price of copper has been volatile for years and few industry analysts are willing to make long term projections. A New York, United States financial institution, Chemical Bank, has recently taken exception to this general rule and made some very interesting projections for the future of the copper market between now and the end of the century.

According to Chemical Bank, real copper prices will rise about 1.0 percent per year for the remainder of this century, substantially less than generally expected. The principal factor in this forecast is that a satisfactory supply-demand situation is expected. Table 1 shows just what copper price projections have been made by the bank.

Chemical Bank points out in its report that major trends to note in the industry are the growing importance of coproducts in determining mine profitability, the entry of energy-related companies into the market, and the developing oligopolistic control of copper production by major multinational companies and Third World host governments.

Declining demand for copper from traditional users, such as the electrical, telecommunications, and plumbing industries, will be compensated by the development of major new markets for copper such as solar energy, electric cars, and desalination programs. The demand for copper is forecast to rise between 2.0 and 3.0 percent per year over the next twenty years—from about 7,300,000 tons in 1980 to about 12,000,000 tons in 2000.

Capacity is expected to increase in line with the projected growth of world demand. Significant additional capacity is already in place and could come on stream quickly, according to the report. In addition, many recently discovered high grade deposits appear profitable even at current copper prices, while the energy companies are likely to proceed with more rapid development of existing ore bodies.

Overall capital requirements of the copper industry in the period 1982-2000 do not appear excessive. However, some less developed economies may experience difficulties. It is estimated that developing countries' external financing requirements for expansion of the copper industry expansion will aggregate over $1,000,000,000 per year in 1980 dollars through the forecast period. Table 2 shows projected capital expenditure for new capacity through the year 2000, both for cases in which coproducts are taken into account and for cases in which they are not.

Successful projects will be those resilient to cyclical movements in underlying demand. The financial future of most of the independent producers, and those developing countries with marginal deposits, must remain in doubt. Such developments may encourage some developing economies to concede a more direct role to major independent mining companies in the mining of their copper and other mineral resources.

Table 1.
Copper price projections 1980-2000

	Average Price (current dollars)	95% Confidence Interval[1]	Average Price (constant 1980 dollars)
1975-1980	75	—	96.0
1981-1985	96	± 5%	79.4
1986-1990	149	± 9%	83.9
1991-1995	228	± 14%	87.4
1996-2000	360	± 20%	98.7

[1] The 95 percent confidence interval indicates a 95 percent certainty that the actual price will lie within the indicated percentage either side of the mean forecasts.

Table 2.
Investment requirements for additions to copper capacity 1980-2000

	Required additions (000 tons)	Total cost (A)	Total cost (B)	Cost per year (A)	Cost per year (B)
		(millions of 1980 dollars)			
1980-85					
Mine	670	2,010	3,200	402	640
Smelter	920	1,640	2,050	328	410
Refinery	980	415	435	83	87
Total		4,065	5,685	813	1,137
1986-2000					
Mine	5,460	16,365	25,900	1,091	1,727
Smelter	6,240	11,700	14,870	780	991
Refinery	6,610	2,800	2,940	187	196
Total		30,865	43,710	2,058	2,914

(A) Includes coproducts valued as copper.
(B) Excludes coproducts

Producers at operating mines have been successful over the past several years in bringing mining costs under control. In the year following October 1973, when the first oil crisis was at its height, average net mine operating costs rose by more than 40 percent. In 1980, by contrast, average costs increased by only 8 percent, notwithstanding escalating oil and energy costs and high general inflation rates in many producing regions.

It is interesting to look at some of the new copper projects in planning or development stages in view of this report. In the case of Ok Tedi, in Papua New Guinea, a project approved and underway, coproduction of gold figures prominently. When looking at energy company involvement, Disputada's Los Bronces property in Chile comes to mind. Involvement of multinational companies with third world host governments is reflected in new mining codes in Argentina, Peru, and Chile, wherein foreign investment is encouraged. High grade deposits that come to mind inlcude the newly-discovered La Escondida deposit of Getty Oil and Utah International. Marginal deposits would include Cerro Colorado in Panama, Quellaveco in Peru, and many of the undeveloped properties in Chile.

The full report on which this column is based is available from Chemical Bank, 277 Park Avenue, New York, New York 10172, United States. Contact Gerald Pollio. —*DAP*

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World Mining

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SPECIAL FOCUS: Slurry Pumping & Handling 46

MARCH 1982
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World Mining

THE COVER

Tailings discharging at a Canadian potash mine are being observed. Economic, efficient pumping of slurry is an integral part of the mining world today, and this month's issue examines this subject in a five-feature *Special Focus. Photograph by Warman International, Inc.*

Features

Special Focus: Slurry Pumping and Handling 46
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Jan Lidin of Sala International explains how greater efficiency in pumping can be attained, while lowering costs at the same time

Prolonging Valve Life 54
The myriad problems that can beset valves, thereby bringing operations to a halt, can be prevented. Curtis Clarkson of The Clarkson Company presents his views

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Capping off the Special Focus, Charles Artus of The Gates Rubber Company describes in detail steps that should be taken when considering slurry hose

Rapid Open Pit Design 66
Flexibility, versatility, and simplicity are the keys. Rudolf Kvapil, John McMorran, and Mark Dotson have the facts and figures

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The fourteenth meeting of the Congress will be held in Toronto, Canada, and it promises to be a meeting not to be missed. George Argall reports

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SPECIAL FOCUS:

In this article, and the four that follow, WORLD MINING takes a close look at one of the most important operations in modern mineral processing

Slurry Pumping & Handling

By **Victor Cabrera**
Project Engineer,
Mountain States Mineral Enterprises
Tucson, Arizona, United States

The word slurry is now commonly used in bulk transportation. Specifically, "slurry" is defined as a mixture of solid particles in a liquid, usually water, from which the solids are easily separated. This is analogous to the passengers boarding a bus for a trip, and then parting from one another at the destination point.

The variety of bulk solids that are handled in slurry form covers a wide spectrum of mining product and waste material. Slurry handling is the key operation of most industrial mineral processing operations that move large quantities of bulk materials to process, distribute, and dispose the generated waste material. The list of materials is endless, including iron ore, copper ore, coal, limestone, phosphates, sand and gravel, bauxite, and tar sands.

Most mining and metallurgical processes of bulk raw material are designed to obtain valuable commodities, namely metal and non-metal minerals and energy material and impurities; the raw material is crushed, ground, and concentrated. Concentration processes such as flotation in metallurgical plants, pelletizing in the iron ore industry, and coal washing, all of which are in slurry form, made possible our access to copper, base metals, steel, and coal in the industrial quantities to which we are accustomed.

Slurry handling of solid water materials and tailings resulting from concentration processes is also widely used. This type of handling makes possible safe and efficient disposal of waste through neutralization of acidic contents while water in the slurry is recovered for re-use. Some of yesterday's tailings are today being treated again using slurry handling.

The Slurry Handling System

Proper understanding of the basis of slurry handling is necessary to successfully apply the technology. Basically, any slurry handling system is divided into two parts:

1. The slurry media of solid and water.
2. The slurry equipment or hardware.

There is close interdependence between the specific slurry and the equipment to handle it. Often, accommodations and trade-offs are made to fit one to the other. For example, slurry preparation is made to suit the equipment; conversely, the fine grinding of raw material that is required for metallurgical flotation, cement manufacturing, and gold liberation from its ores, makes efficient slurries. On the other hand, dredging operations involving rock and gravel require special equipment to keep large solids in suspension.

The Slurry Media

The purpose of slurry handling is the transportation of solids suspended in water via pipeline. Thus, it is desirable, from an economic standpoint, to obtain a slurry with the maximum solids concentration that is compatible with the equipment capabilities.

During slurry handling, the slurry media behaves like a fluid. The velocity of the slurry inside the pipeline is sufficient to keep the solid particles in suspension. The parameters affecting slurry hydraulic behavior inside the pipeline are the solids' particle size and specific gravity, and the solids concentration. These affect the tendency of solid particles to settle and the density of the slurry.

The parameters affecting the wear of pump and pipeline materials are the solid particle abrasiveness and the corrosive effect of the slurry media. Solid particles that are angular in shape with a high hardness index are more abrasive than other particles. The abrasiveness is increased in function of flow velocity, an effect analogous to a river eroding its banks more rapidly at flood.

The corrosiveness of the slurry media is chemical in nature. Dissolved oxygen and residual acids tend to attack metal surfaces, especially at the intra-granular metallic boundaries. Oily compounds from flotation and ion exchange processes destroy natural rubber. Some synthetic elastomers, such as neoprene, used as rubber substitutes, are impervious to attack from petroleum oils and some chemical action. On the other hand, the slurry media can be treated for chemical neutralization and oxygen removal with special additives if they do not affect the process. This treatment is beneficial to the pumping equipment and the pipe material downstream in the slurry flow.

The slurry equipment: Process plants and long distance slurry pipelines handle slurry with pumps, valves, pipeline, and control instrumentation. As any steady state continuous operation, slurry handling can be partially or totally automated with remote controlled instruments, telecommunications, and computer control. These controls keep the slurry system in balance.

The most common pump for slurry handling today is the centrifugal type, which is capable of handling up to 20,000 gallons per minute with 200 feet of head per pump stage. High pressure applications are performed by reciprocating pumps. Other types of special pumps, such as diaphragm and Moyno, are more restricted in their use.

Slurry pumps are divided according to their mechanical features as follows:

- Centrifugal type: horizontal, vertical, and submersible
- Reciprocating type: plunger and piston
- Special design: diaphragm, lock hopper, rotary ball, Mars pump, Moyno progressing cavity pump, hose pump, cylinder diaphragm.

Photograph by Warman International, Inc.

TAILINGS discharge at the end of a 3,650-foot pipeline at a Canadian potash mine. Solids deposit is 3,000 feet long, 1,000 feet wide, 150 feet high. Runoff goes into a settling pond.

Centrifugal pumps

Centrifugal pumps are an adaptation of ordinary water pumps with the necessary improvements for slurry handling. Design of slurry pumps includes the selection of materials constructed to resist abrasion, corrosion, and the extra load of heavier-than-water slurry. Since wear is a funtion of velocity, the pump must operate at a low rotational speed and the impeller has to be truly a radial flow design. Radial flow attained at low revolutions per minute, compared with axial flow, minimizes abrasion wear.

Centrifugal pumps are identified by their specific speed (Ns), which relates to flow (Q) (gallons per minute), head (H) (feet), and shaft revolutions per minute (n) as follows:

$$Ns = nQ^{1/2}/H^{3/4}$$

For slurry service, the specific speeds of centrifugal pumps with radial vane impellers vary from 600 to 1,800 revolutions per minute.

Abrasion wear: There are three main types of abrasion wear:

- Gouging abrasion when coarse, angular particles tear fragments of the wearing surface. Examples are gravel dredging and primary cyclone feed.
- Grinding wear of fine particles crushing between two surfaces in close proximity. For example, the side clearance between the impeller and the stuffing box.
- Erosion abrasion caused by the impingement of impact of solid particles on the wearing surface. Examples: the cutting wear and deformation wear that are respectively parallel and normal to the flow direction.

Abrasion resistant meaterials: Tough materials are used for gouging abrasion. Cast iron, often with 3 percent nickel, is the basic pump material employed when protection against mild corrosion is needed. Ductile-iron and cast steel offer extra strength in high pressure applications or when the pump is exposed to high impact shock. Austenitic manganese steels are tough, free of residual stresses in castings, and they also work-harden with use, so they are preferred in dredge and gravel pumps.

The use of composite materials is prevalent for grinding and erosion abrasion without unduly high impact shocks. Metal liners made of Ni-Hard and heat-treated high-chromium iron with Rockwell C hardness numbers between 55 through 63 are excellent for these two types of abrasion.

Natural rubber is the most common non-metallic liner used for abrasive service, provided the liquid phase of slurry contains no hydrocarbon, which destroys the rubber. Man-made elastomers such as butyl rubber, neoprene, nitrile, hypalon, and polyurethane are also used. Resistance to erosion abrasion is enhanced by elastomers with high resilience characteristics, low hardness, and high tear and cut resistance.

Ceramics are applied less frequently as liner material because of their low resistance to thermal and impact shocks. An exception is the solid silicon carbide refrax type ceramic for selected fine solid particle slurry applications.

Materials resistant to chemical corrosion are rubber, man-made elastomers, ceramics, and steel alloys of nickel, chromium, and molybdenum. Corrosion attack of the metallic intergranular boundaries induces stresses affecting the life span of the pump. For this reason the metallic liners should be evaluated for the particular applications to offset the possibility of the development of corrosion cracks in the pump.

Pump wearing areas: The areas of the pump most prone to wear, in order of severity, are as follows:

- Suction side wear plate liner. The replaceable liner is periodically rotated to equalize wear. A replaceable wear plate is also provided on the gland side adjacent to the impeller.
- Impeller, particularly at the eye vane inlets, suction side impeller shroud, and the vane tips. The closed impeller design is preferred to the open impeller because it is more robust and efficient. The three or four vanes in the impeller are extra thick on the parts subject to most wear.
- The casing and side walls adjacent to the impeller tips. Replaceble liners protect the casing from wear. In the case of metal liners, the mating faces are accurately ground to match the casing surface and permit a close fit joint when the casing is bolted together.

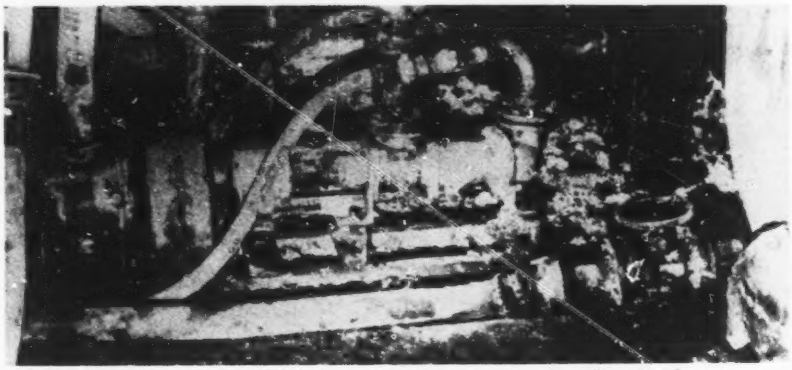
All elastomer liners are pressure molded, easy to remove and provided with bolts to secure the liners firmly in place. For some severe abrasion applications, the pump casing is relined by trowelling epoxy "Nordbak" paste with embedded "Coors" ceramic beads. The ceramic beads held in the cured "Nordbak" epoxy matrix form an effective anti-abrasive surface.

- The stuffing box packing and sleeve. Unless precautions are taken to prevent the entrance of solids into the stuffing box, rapid wear will result in the shaft sleeve. Current pump designs include hydrodynamic vanes on the impeller facing the stuffing box seal. These vanes minimize the pressure at the seal and its contamination with slurry material.

Stuffing box mechanical seals are in common use. Some pump manufacturers favor the centrifugal type and the packed gland seal. This arrangement combines the hydrodynamic sealing vanes with packed box arrangement of graphite asbestos or teflon filled asbestos split rings. However, double seals with a clean barrier liquid, gland water, have proved highly successful. In these cases, water at higher pressure than inside the pump is injected through the lantern ring of the stuffing box. One disadvantage of the method is the dilution of the slurry with gland water, which by design can be minimized.

Bearings for slurry pumping are designed for heavy duty service, with a calculated life of 50,000 hours, which is higher than for water pumps. Oil lubricaton is preferred over grease. Sealed bearings are easily interchanged at short notice.

It has been pointed out that low revolution per minute operation is of the utmost importance to wear reduction. Therefore, electric motors or Diesel engines use V-belt drives and gear reducers to attain the required speed. V-belt drives are popular because pump speed is adjusted by changing the pitch diameter of the V-belt sheaves.



SCREW PUMP from Netzsch-Mohnopumpen is shown at work underground.

Although gear reducers are used on pumps with motors having 300 horsepower and above, V-belt drives are satisfactory for large motors and engines in the range of 1,500 to 3,000 horsepower. Motors and engines for slurry service must be rated with an adequate margin, say 20 to 40 percent, to cover upset conditions that may occur during start-up and emergency shut downs. Pumps driven by gear reducers often have variable speed couplings for slurry flow control, a feature that can also be adopted to V-belt drives.

Reciprocating pumps

The mud pumps used in the oil drilling industry were developed to generate high pressures and to resist the attritional effects of abrasive laden slurry. Based on this experience, the reciprocating slurry pumps, larger in size and capacity, are standard equipment in long distance slurry pipelines.

Reciprocating slurry pumps are more efficient than centrifugal pumps because of the positive displacement feature. They are also more costly because of their close tolerance fabrication and higher weight compared with centrifugal pumps. Pistons and plungers in the reciprocating pumps induce pressure on the incoming slurry admitted to the pumping chamber. This chamber has valves to admit the low pressure slurry and discharge the high pressure slurry.

Piston reciprocating pumps, which are double acting, are applicable to slurries that are not very abrasive and for pressures up to 2,000 pounds per square inch. These high volume pumps are used for coal, phosphate sized to 8 mesh, and limestone sized to 28 mesh.

The plunger reciprocating pump is single acting and it therefore delivers less volume than the piston type. The pump is adequate for abrasive and fine particle slurries such as hematite, magnetite, and copper concentrates with pressures up to 3,000 pounds per square inch. The small velocities of slurry flow tolerated in the reciprocating pumps reduces their capacity considerably. For this reason the pumps are multiplexed (parallel multi-unit mounting). In addition, several multiplexed pumps are needed to attain the capacity necessary for a given application. For example, if up to five triplex pumps installed in parallel are needed for a certain pumping station, one of the triplex pumps is always on standby for continuity of operations during the repair or maintenance of any other pump in the pumping station.

Reciprocating slurry pumps are designed so that the parts subject to the deteriorating effects of slurries can be easily and quickly replaced. The parts more subject to wear are the pump valves and valve seats because of slurry movement and constant metal to metal pressure during the closing of the valves. In the piston pump, the piston that displaces the slurry runs in a renewable metal cylinder or liner. The piston rod runs through its packing and presents a second area of sealing and wear. On the other hand, the plunger pump with its packing is the only area subject to wear.

It has been established that slurry velocity should not exceed 12 feet per second through the valve, to minimize erosion effects. This dictates the amount of bearing area that can be used. Several materials have been employed to extend the life of valves and valve seats, including steel alloys and polyurethane. Several configurations have also been tested to provide good seat at valve closing and the appropriate distribution of the valve closing load. Valve life varies from as low as 100 hours to 1,000 in abrasive slurries; in less abrasive slurries, such as coal, the valve life approaches 1,200 to 1,800 hours.

The purpose of packing is to close the clearance gap between the piston rod or plunger and the stuffing box parts. It effectively prevents slurry flow outside of the pumping chamber while permitting the reciprocating movement of the piston rod or plunger. Hard packing, which is to be lubricated for high pressure service often reaching above 2,000 pounds per square inch, is preferred over soft packing.

The introduction of water flushing into the stuffing box prevents slurry migration outside the pumping chamber and into the packing when the plunger is on the suction stroke, and it is entering the packing. A positive displacement pump is used for flushing because it is desirable to supply water at a constant metered rate. The flushing water is introduced by a special lantern ring to the bottom of the plunger. About 4 gallons per minute of flushing is required per plunger.

The drives for reciprocating pumps are usually large electric motors, Diesel engines, and turbine engines. The driving train thus contains gear speed reducers and variable speed couplings and controls. One limitation on driving revolutions per minute is the need to maintain the slurry velocity at a rate below 12 feet per second at the inlet check and outlet check valves. Also, it is usual to have one standby unit ready to go on line to replace another unit for repairs or maintenance.

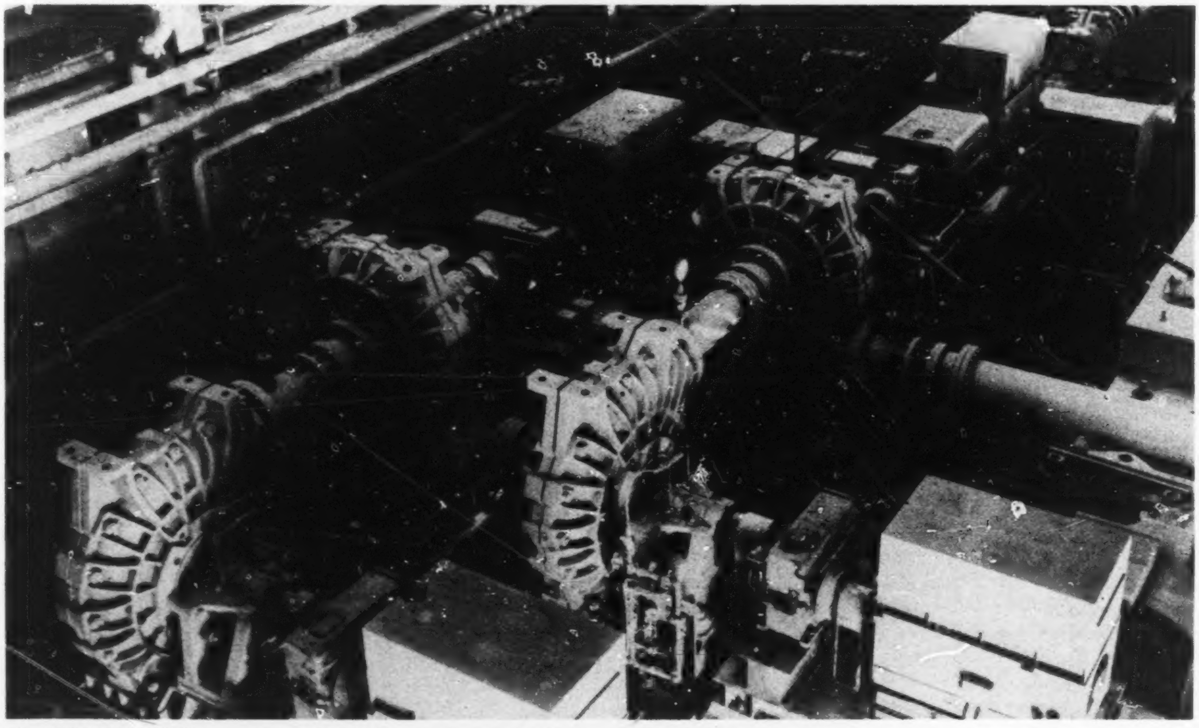
Non-contact pumps

Non-contact slurry pumps, which are different from centrifugal and reciprocating pumps, are gaining acceptance today. In the non-contact pumps, the abrasive slurry is isolated from the pumping parts subject to wear with a liquid or elastomer interface. The main advantage of non-contact pumps over other pumps is their long life between maintenance periods. Another advantage is that non-contact pumps' pumping equipment can be located away from the pressure vessels in contact with the slurry.

Liquid interface pumps: The Mars pump and the lock-hopper pump use oil and water, respectively, to interface slurry during pumping operations. Mitsubishi's Mars pump is a duplex double acting piston pump using an oil barrier that prevents contact between the slurry and the pistons and cylinders. The lock-hopper pump has its water and slurry phases separated with free moving rubber balls in the pressure vessel used for pumping. The Mars pump is used successfuly to hoist deep gold ore slurry in South African mines. The lock-hopper pump is a safe and efficient coal transporter, used in English underground collieries to transport coal from underground to the surface.

Elastomer interface pump: The ubiquitous diaphragm pump is a good example of a long lasting pump. It has an elastomer body with an inlet check valve to admit slurry and a discharge valve. Diaphragm valves are basically for low pressure applications (below 100 pounds per square inch). Examples include the Warren Rupp Company's SandPiper air powered double diaphragm pump and the Dorr OGS pump.

The high pressure hydraulic exchange pump (Zimpro Inc.) is a well-tested non-contact slurry pump for high pressure, up to 3,000 pounds per square inch applications. The basic operation consists of positive feeding of low pressure slurry to a bag-shaped diaphragm, which is located inside a pressure vessel filled with oil. Hydraulic pressure applied to the oil forces the slurry out of the diaphragm at high pressures. Pumping proceeds in a continuous manner,



TACONITE TAILINGS pump house. Each of the pumps weighs in excess of 40,000 pounds. Tailings are pumped 23,000 feet at a rate of some 15,000 gallons per minute.

ceeds in a continuous manner, using two pressure vessels alternately with inlet check and outlet check valves.

Screw pumps

Screw pumps are in a class by themselves. They are highly versatile for difficult-to-handle slurries that are viscous, abrasive, and contain some large particles. The rotating screw generates progressing cavities, which deliver uniform and continuous flow with pressures up to 1,000 pounds per square inch and self-priming suctions up to 28 feet. Examples are the Moyno and the Pumpenfabrik Wangen GmbH pump.

Instrumentation and valves

Instruments and valves for slurry handling are basically the obstructionless type. Instruments mounted outside the slurry pipe by indirect methods measure slurry flow velocity, density, and pressure. Contact type instruments measuring pH and temperature are secondary in importance to the three parameters just mentioned.

Instruments: Magnetic flowmeters and ultrasonic Doppler effect instruments measure flow velocity. Nuclear gauges and ultrasonic sound absorption instruments measure the slurry density. These are calibrated against known standards and relay measuring inputs with transducers. These transducers convert the magnetic, ultrasonic, and pressure inputs into electrical signals for reading and control.

Once the operating parameters of flow velocity, slurry density, and pumping pressure are defined for steady state conditions, the desired control can be established. These controls are either manual or automatic. However, manual overrides are still necessary in automated systems in order to fine tune the operation of the slurry system during start-up or emergency conditions. Operators will develop confidence as they find that slurry systems are rather stable within a narrow band of designed flow velocities, slurry densities, and pressures before developing upset flow condition. The proper identification of those limits with alerting red lights or bells enable the operators to institute prompt remedial actions.

Instrument readouts at key points in the slurry pipeline; namely, pump feed, pump discharge, pipeline intermediate points, and discharge, are normally redundant, to prevent breaks of data gathering due to temporary failure of a given instrument. The additional cost of providing redundancy is amply compensated by the benefits of effective monitoring of the slurry system.

Valves: Valves for slurry application are the full-flow type because flow obstruction can cause deposition of the solid phase and eventually induce plugging of the pipeline. Full-flow plug valves are used in full open and full close positions only. Special attention is given to valve operation for flow diversion; the valve closing the flow, and the valve opening to divert this flow are interlocked so that flow velocity and continuity are minimally affected. This valve interlocking is usually done by instrument control, and solenoid actuators of the fail-safe type, and motor operated valves.

Throttling valves are occasionally used for flow branching and energy dissipation. These valves are designed for smooth flow under velocity change that often create a Venturi effect. Ceramic annular chokes restricting flow by increasing friction are used to dissipate extra head in the slurry system. Throttling valves constricting flow are of two kinds: the diaphragm valve with an annular constriction, the butterfly valve with a smooth face and shape, and the flexible hose pinch valve, in which flow is throttled by constricting the hose. These throttling valves are lined with abrasion-resistant elastomers, metal alloys, and ceramic.

- Flow velocity instruments:
  Magnetic flowmeter, Ohmart
  Ultrasonic flowmeter, Polysonic
- Pressure:
  Diaphragm sensing, Tescom
- Throttle valves:
  Pinch valve C, Clarkson
  Eccentric butterfly, Duriron
  Flexible hose pinch valves, Larox
- Density meter:
  Nuclear gauge, Ohmart
  Ultrasonic absorption, Envirotech
- Plug valves:
  Full flow, DeZurik
- Computer instrumentation
  Digital, Foxboro, ITT, 3M

Pipe material

Slurry pipelines can operate without pumps but not without the pipeline. In fact, there are many gravity-type slurry pipelines handling mineral tailings and concentrates where the main equipment is just the pipe material. This fact underscores the importance of pipe material selection and design, as these two factors affect the longevity and efficient functioning of the slurry handling system.

Steel: Carbon steel pipe is most readily used because of its economy, versatility, and ease of construction. Several grades of carbon steel are available from the ASTMA-53 steel, which has yield strength of 30,000 pounds per square inch, up to the API-SLX-60, the

How to receive more information

To receive more information on any of the slurry pumping and handling hardware described in this article, use the reader service card on page 17, and circle the numbers of any of the categories listed below. Your inquiry will be forwarded to manufacturers of the types of equipment for the category indicated.

Slurry pumps	
Pumps with metal and/or rubber liners	Circle No. 200
Metal dredge pumps	Circle No. 201
Pumps with recessed impellers	Circle No. 202
Submersible slurry pumps	Circle No. 203
Screw centrifugal pumps	Circle No. 204
Piston and plunger pumps	Circle No. 205
Elastomer interface pumps	Circle No. 206
Screw pumps	Circle No. 207
Pump drives	Circle No. 208

Slurry handling materials	
Rubber lining material	Circle No. 209
Plastic pipe	Circle No. 210
Rubber hose	Circle No. 211
Steel pipe	Circle No. 212

Slurry valves and instrumentation	
Slurry throttle valves	Circle No. 213
Slurry plug valves	Circle No. 214
Flow velocity instrumentation	Circle No. 215
Pressure sensing instrumentation	Circle No. 216
Density meters	Circle No. 217
Computer instrumentation and supervisory control	Circle No. 218

strength of which doubles this figure.

Special low alloy carbon steels containing manganese and nickel have yield strengths up to 100,000 pounds per square inch; for example, Transol from Jones and Laughling Steel. This pipe and the hardened wall pipe, 500 Brinell hardness number, are designed for improved abrasion and corrosion resistance. However, these materials are more costly and less standardized than carbon steel.

Plastic and composite material: The next most popular pipe material is the assortment of plastics including PVC, polyethylene, polypropylene, and the extra strength high density and ultra high molecular weight polyethylene. Plastic pipes are lightweight, versatile for a variety of slurry applications and rather easy to install. Plastic pipe, like steel, is easy to string weld or join by a variety of couplings. A major advantage of plastic pipes is their resistance to corrosion, and if properly selected, resistance to abrasion. On the other hand, plastic pipes are restricted to internal pressures below 200 pounds per square inch while steel pipe has no pressure limitations to speak of. This is a reason why composite steel body pipes with liners of elastomers, plastic, and expoxy are in vogue today.

Asbestos cement: The asbestos cement material (Johns Manville Transite) is commonly applied especially in gravity ore tailings pipelines. This pipe is widely available and it is resistant to abrasive slurries requiring a minimum of maintenance once it is installed overland or buried. It is applicable for low pressures not exceeding 200 pounds per square inch. Composite steel and cement asbestos pipe has the advantage of high strength, resistance to abrasion, and string welding features for efficient field construction.

Elastomers: Natural rubber and elastomers are used for low pressure and short distance slurry pipelines, such as in process plants. They resist abrasion and corrosion extremely well. For this reason, composite pipe of carbon steel body and rubber-lined pipe material are used for abrasive slurries.

Specialty materials: Chemically corrosive applications require costly specialty pipe materials, including stainless steels 304 s.s.and 316 s.s. and proprietary materials such as Monel, Inconel (International Nickel), and Hastealloy (Union Carbide) that are nickel, manganese, chromium, and vanadium steel alloys. These materials as well as other metals including aluminum, titanium, and zirconium, are suitable for low abrasion slurries at relatively low flow speeds.

Table 1.
OGJ Morgan pipeline cost index

Cost Component	1977 Index	1981 Index	Escalation
Steel line pipe	139	199	43 percent
Pipeline construction	128	177	27 percent
Pipe coating	124	166	34 percent
Pump equipment	144	201	40 percent
Electric motors	159	239	33 percent
Steel storage tanks	140	193	38 percent
Radio & microwave equipment	115	145	26 percent

Another specialty material, fiberglass reinforced polyester (FRP), is resistant to corrosion but it is seldom suitable for slurry application because the pipe is not resistant to abrasion.

Pipe protection

Protection of pipe material for slurry handling is both internal and external. Internal protection includes measures to minimize abrasion and corrosion wear and structural protection against underpressure and overpressure caused by upset conditions. External protection is necessary to shield the pipe from such things as hostile environmental temperature changes, ultraviolet sunlight radiation, electrochemical attack of moisture-laden earth, and for security reasons.

Internal abrasion-corrosion: Carbon steel pipe has allowance in wall thickness for abrasion-corrosion wear. This wear is minimized by using low flow velocities, say below 10 feet per second, and by the corrosion inhibitors that are added to control pH and to remove oxygen in the liquid phase of the slurry. Popular additives are lime, soda phosphate compounds, and calgonite.

Although about twice as expensive as carbon steel, composite material pipe using highly resistant to abrasion-corrosion plastic, epoxy, and rubber liners, is very successful for trouble-free, high-pressure slurry handling.

The high molecular weight polyethylene pipe, such as Phillips' Drisco, is recommended for low pressure application, such as in-plant and gravity lines, because of its abrasion-corrosion resistance, its economy of installation and its wide availability. The same can be said of the asbestos-cement pipe, which is also economical.

Interal vacuum and overpressure: Underpressure or vacuum in the pipe can cause its collapsing. Adequate protection is made with pipe vents located at high points along the pipeline route, which admit air to compensate for vacuum created by slugs of slurry separated by differential overspeeding. Conversely, overpressure can rupture the pipe if the hoop strength of the pipe is exceeded. Overpressure, especially in reciprocating pumping installations, is prevented by locating rupture discs on the discharge secton of the pump. These discs break under a set load, functioning much like fuses in electrical systems. The rupture discs seal the top of special tanks, which are mounted on the pipe. These tanks function as pulsation dampeners. Pulsation must be controlled in reciprocating pumps in order to prevent damaging structural stresses to the pump body and pipe.

External protection of pipe material: Only metal pipe requires external protection such as paint for above ground pipe. When metal pipe is buried it is lined with anti-corrosion multi-layer coatings of tar or epoxy plus tar paper wrapping. The external coating is tested with high voltage spark (Holiday) to check the thoroughness of the protective cover. In addition, buried metal pipe requires cathodic protection to prevent electrolytic wear of the metal. Impressed electric current and/or zinc spend anodes prevent this type wear.

Plastic, asbestos cement, and rubber pipes are resistant to atmospheric agents and they do not require external protection when installed above or below ground. All are also unaffected by ultraviolet sunlight radiation, with the exception of some plastic materials such as PVC.

Cost considerations

Although recent materials and labor prices have tended to stabilize due to the current recession, pipeline capital and operating costs escalated during recent years at approximately seven percent per year. Using the 1977 prices given in the reference (Slurry Handling by V. Cabrera), a factor of 1.4 should be applied to update prices in 1982, as the compound interest, or inflation, of five years at seven percent is equal to 40 percent. This escalation is shown in more detail in Table 1.

Reference

Pipeline Economic Report, Oil & Gas Journal, November 23, 1981. ■

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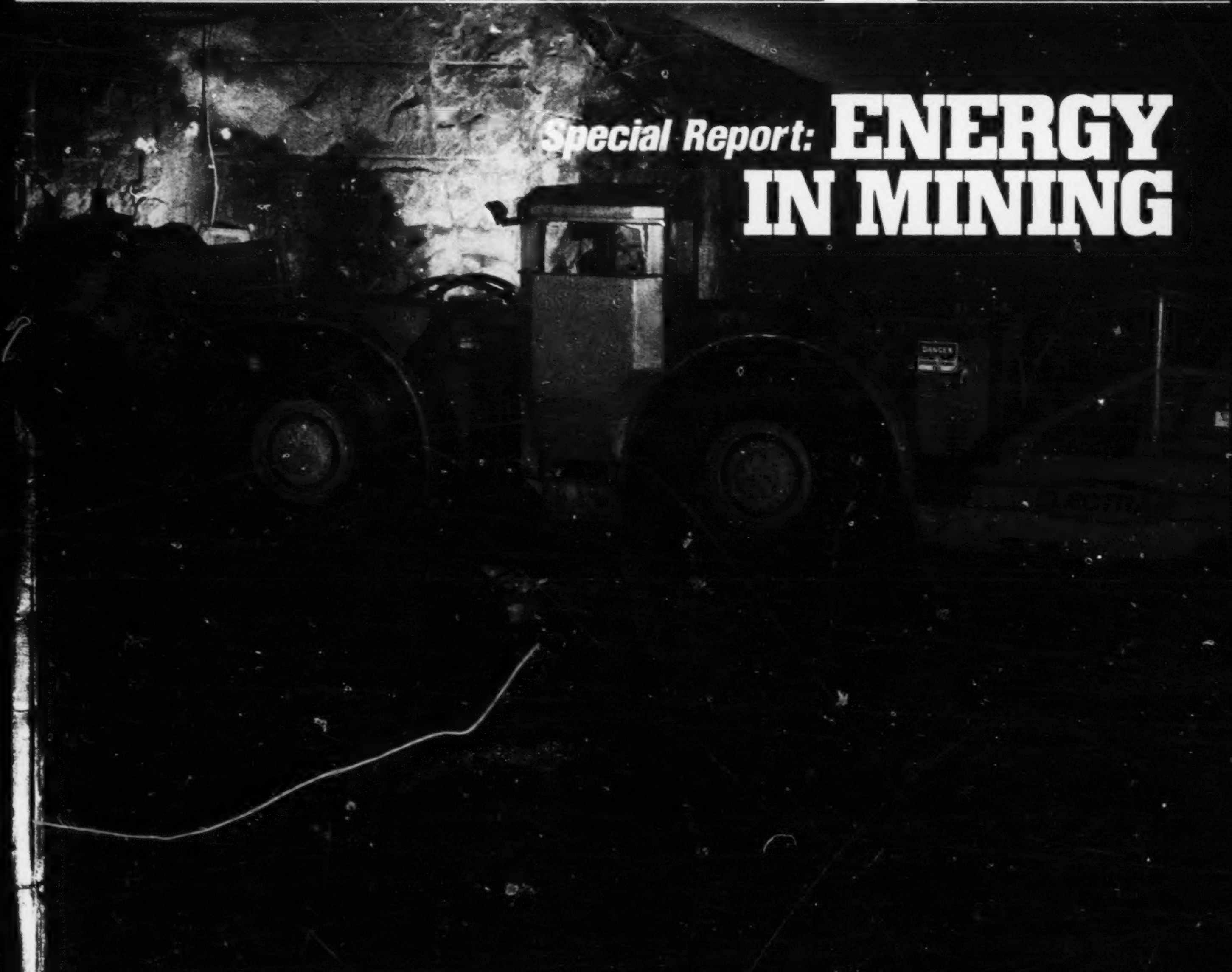

Special Report: ENERGY IN MINING

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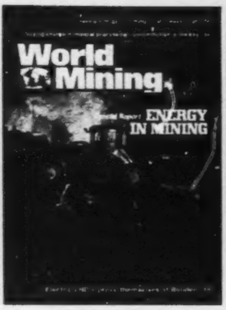

THE COVER

A Wagner EST-5B ELECTRAM® is the first unit in regular production operations at a new Swedish mine specifically designed for electric LHD loading. This new unit from the United States mine equipment manufacturer is in a production stope at Boliden Mineral's Hornträsk mine, and it represents the first step in a new era. *Photograph by Boliden Mineral AB.*

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Energy conservation has been called the fifth fuel. A vast amount of work is being carried out by mining companies around the world to get as much out of this "fifth fuel" as possible. Hand-in-hand with conservation goes the application of cheaper power sources.

Saving energy in mining—1,001 ways to go

By **John R. Chadwick**
Associate Editor

For each $1.00 increase in the price of a barrel of oil, $0.10 to $0.15 is added to the total energy bill for producing 1 kilogram (2.2 pounds) of nickel from a good grade lateritic ore. Ever since 1973, industry in general has been trying to reduce its consumption of energy in order to offset massive increases in power costs. The industrial nations have had to develop new energy economies. There has been a move to conserve by using less, or more importantly, by increasing productivity and by substituting other energy sources for oil. Between 1973 and 1980, for example, the energy consumption of industry in the United States increased by less than 3 percent, while industrial production rose by more than 13 percent.

In 1979 Aldo Barsotti came up with the following conclusion as a result of his Ph.D. thesis at Case Western Reserve University: the world has plenty of raw materials to meet the demand for aluminum, copper, and iron for the rest of the century, but it won't have enough energy to produce these vital metals. Barsotti's computer model suggested a widening gap between metal energy requirements and energy supply, with a one-quarter shortfall of needed energy in the year 2000. In the study, aluminum, copper, and iron were singled out because "they are three basic metals to any industrial country or to a developing country seeking economic growth."

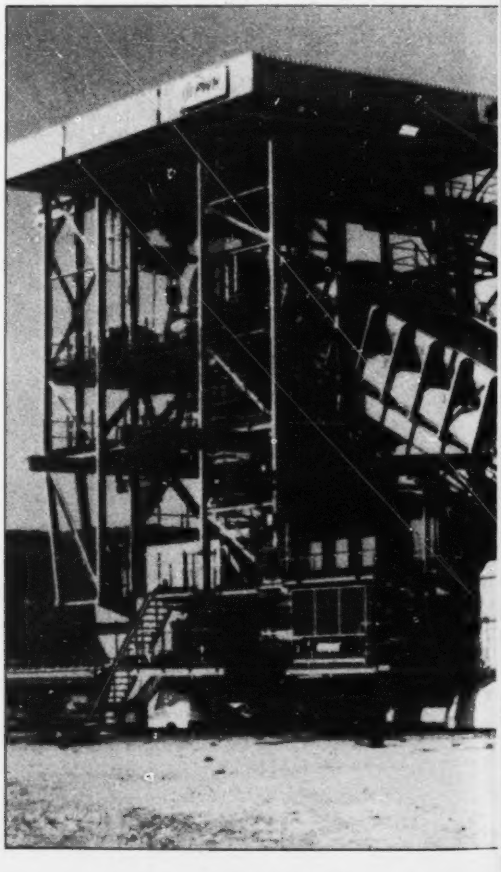
The study stressed the need to improve energy efficiency and conservation. Table 1 shows some interesting figures from this study. Table 2 (from Kellogg) is based on data from Battelle-Columbus Laboratories and divides primary materials into those that are energy intensive and those that are not.

The struggle to reduce power costs is as true in the world of mining as in any other industry. Recent years have seen a great deal of development in this field. One of the most significant has been the trend to use electrical power, as much as possible, instead of Diesel power for mining vehicles. This development has been seen in large capacity dump trucks, hydraulic excavators, articulated trucks, load-haul-dump units, underground service vehicles, and many other units essential to mineral production.

At this present time of low prices for most mined products, the importance of reducing energy costs, such a major component of total operating costs, becomes paramount. This fact has been underlined by the many innovative tech-

Table 1.
Energy consumption per unit output in metal production

Metal	Process	British thermal units per metric ton output
Aluminum	Bauxite mining and treatment	566,000 per ton ore
	Alumina production	23,480,000 per ton alumina
	Aluminum production	
	Thermal energy	216,650,000 per ton metal
	Hydroelectric	91,640,000 per ton metal
Copper	Open pit mining and processing	421,000 per ton ore
	Underground mining and processing	518,100 per ton ore
	Smelter production	29,950,000 per ton metal
	Refined copper production	15,440,000 per ton metal
Iron	Open pit mining	1,213,000 per ton ore
	Underground mining	1,290,000 per ton ore
	Pelletizing	1,320,000 per ton pellets (63 percent Fe)
	Blast furnace	22,980,000 per ton pig iron
	Crude steel production	
	Open hearth	5,520,000 per ton crude steel
	Basic oxygen	2,480,000 per ton crude steel
	Electric furnace	9,300,000 per ton crude steel

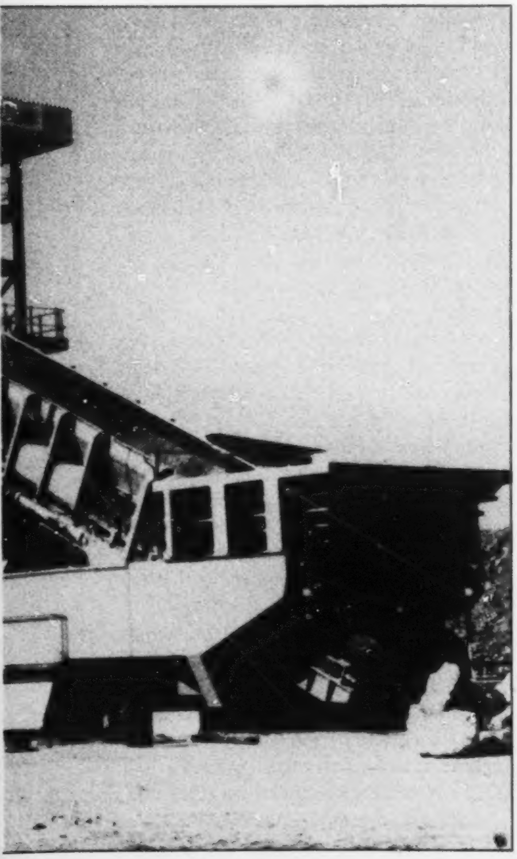


niques that the mining industry has seen develop in the energy saving field over recent years.

In underground operations it is universally accepted that ventilation requirements are the major energy consumer and the trend towards the use of more electrically-powered vehicles underground, as opposed to Diesel power, can only help reduce this cost. In open pit mines, it is the transport of ore and waste that consumes most energy. The application of trolley-assisted trucks, in-pit crusher, and conveyor systems are all aimed at reducing operating costs.

Ventilation Considerations

Recently it was stated that, in order to achieve better energy economy, it is necessary to have good control equipment, dry ventilation shafts, variable speed fans, and control of the air flow within the mine (see World Mining, April 1979, pages 58 and 59). This was concluded after an energy consumption study carried out at Boliden's Udden mine in Sweden.



PWH'S MOBILE CRUSHER, largest in the world, can handle up to 2,700 tons per hour.

A major development in reducing ventilation energy is the Ventcon system developed by Outokumpu (Finland). It is based on the idea of dividing ventilation air more effectively around the mine. Ventcon controls the mine's system of fans and ventilation doors such that ventilation is highest where most is required, usually where Diesel equipment is being used. Similarly, areas where little or no mining activity is proceeding receive sufficient, but smaller, amounts of air. This careful control not only limits the waste of air but allows the use of smaller, less energy-consuming fans. At Outokumpu's own Pyhäsalmi mine, it is estimated that Ventcon saves 800,000 kilowatt hours of power per year, worth some $50,000. In addition, it has saved $60,000 in capital expenditure on fans and air heating.

In South Africa, developments in refrigeration lead the world in reducing the energy consumption of systems required to cool the ambient air in hot mines. It has been estimated that the development of the chilled service water system (see World Mining, August 1981, pages 41 to 43) has saved the deep level gold mines some $42,000,000 per year.

Although chilled service water has only recently been fully developed, a new, potentially better, system is being designed which will utilize ice for cooling. Its major advantage is that the quantity of ice required constitutes only one quarter of the quantity of chilled water needed to provide the same cooling capacity. The new design should allow for substantial cost savings and practical benefits, resulting from a much smaller refrigeration distribution system, with smaller pipes, pumps, pump chambers, electrical power supply equipment, heat exchangers, and many other components that go to make up a complete system. The electrical power required to operate this distribution system would also be substantially reduced. The Chamber of Mines of South Africa is currently carrying out pilot plant tests.

As already mentioned, a change from Diesel-powered to electric-powered vehicles underground will reduce ventilation requirements and, therefore, also cut energy costs. In addition, electrical power is cheaper than Diesel power. Service vehicles, usually low horsepower units, could utilize more battery power. However, the relatively short operating time and power of such units limits their application. In addition, much of the work of these machines is not in areas where ventilation is a problem.

Battery power is totally unsuitable for the low-profile articulated trucks used underground, as these units need high power and must be able to work continuously for prolonged periods to achieve maximum productivity. However, such units are often loading from muck piles relatively close to main haulage ways. Therefore, it would be possible to use them with a trolley-assist system. At the moment, such units are only in the prototype stage. For example, M.A.N.-GHH have a 15-ton unit in the develop-

Table 2.
Energy requirements for production of selected primary materials, in British Thermal units per ton

	Energy-intensive major materials		
Magnesium ingot	358,000,000	Sodium metal	92,000,000
Aluminum ingot	244,000,000	Titanium oxide, pigment	86,000,000
Phosphorus (elemental)	172,000,000	Ferrosilicon (50% Si)	77,000,000
Nickel cathode	144,000,000	Zinc, slab	65,000,000
Ferrochrome, low C	129,000,000	Ferrochrome, high C	61,000,000
Copper, refined	112,000,000	Ferromanganese	50,000,000
	Energy-intensive minor materials		
Gold bars	59,000,000,000	Ferrovanadium	490,000,000
Gallium metal	12,000,000,000	Titanium sponge	410,000,000
Germanium metal	2,100,000,000	Lithium hydroxide	400,000,000
Silver bars	1,500,000,000	Mercury metal	400,000,000
Zirconium sponge	1,300,000,000	Tungsten powder	350,000,000
Uranium oxide	900,000,000	Tin ingot	190,00,000
Hafnium sponge	660,000,000	Molybdic oxide	150,000,000
	Low energy-intensive materials		
Sand and gravel (sized)	56,000	Kaolin	2,800,000
Crushed and sized stone	56,000	Gaseous N_2	2,900,000
Rock salt	170,000	Arsenic oxide (by-product)	3,000,000
Sulphuric acid (Frasch sulphur)	830,000	Common brick	3,500,000
		Gaseous O_2	3,600,000
Calcined gypsum	1,500,000	Fireclay brick	4,200,000
Ground feldspar	2,000,000	Liquid argon	4,300,000
Emery, abrasive grain	2,100,000		

ment stage, and at Malmberget in Sweden, LKAB is working on an underground trolley-assisted truck project. Bearing in mind the recent success of trolley-assisted trucks in open pit mines, this idea could well see some application in the future. Also, underground Diesel trucks can be replaced by a conveyor belt, as is the plan at Samim's Masua mine in Sardinia (WORLD MINING, January 1982, pages 36 to 39).

When choosing a conventional Diesel truck for underground use, it is important to consider its grade climbing capability. A high grade climbing capability can save money in two important ways. The steeper the gradients can be, the less development work has to be carried out. Secondly, correct manipulation of grade, spiral length, etc., at the design stage, carried out properly, can give optimum fuel consumption.

Electric LHD's, those equipped with a cable reel to connect with a power source, have been available to the mining industry for many years. However, interest in such units has increased dramatically during recent years. The major manufacturers of LHD's now produce electric drive units. A detailed discussion of the electric LHD's will not appear here since there is a whole article devoted to experience with these units in Sweden starting on page 49. The Swedish requirement has been for the larger capacity units, starting from five yards. An example of the successful application of small electric LHD's is the Panasqueira (Minas de Borralha SARL) tungsten mine located in Portugal. At this mine, more than 1,000 hours of successful operation of a Wagner two-cubic-yard electric scoop led to orders for five more units.

Suffice to say that cable-reel LHD's are proven mining equipment, which not only offer benefits in reduced fuel bills, but also save ventilation costs since such units are usually working in the areas where the ventilation problems are the greatest.

Hydraulic Mining

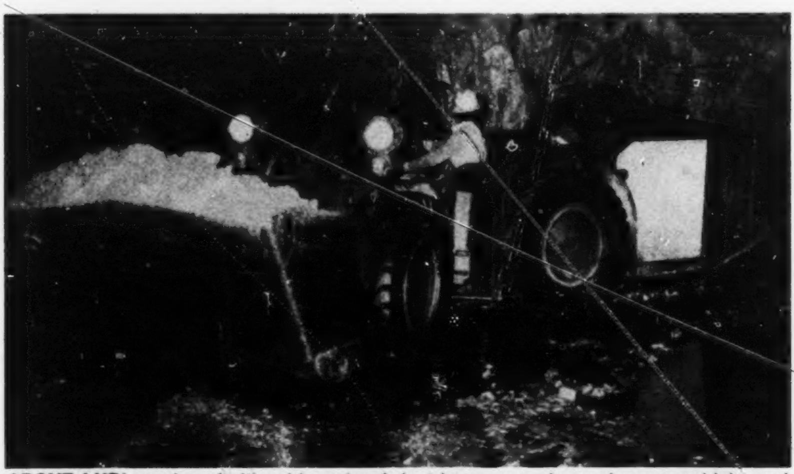
Still very much in its infant stages, hydraulic mining offers the use of water power for the extraction and transport of ores, most particularly coal. A famous example is B.C. Coal Ltd.'s Sparwood, Canada, operation (refer to WORLD COAL, July/August 1981, pages 48 to 51). Among the manufacturers working on such systems are Siemag Transplan (West Germany), Babcock Hydraulic Handling (United Kingdom), and Nikex (Hungary).

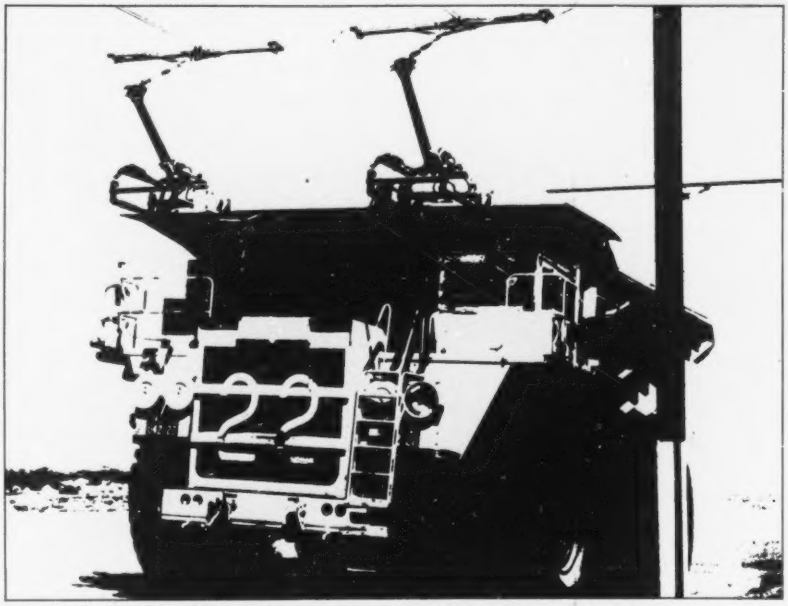
It was Siemag Transplan that supplied equipment to the Hansa coal mine in West Germany. Here coal was extracted from the seam by monitors operating at pressures of 80 to 100 bar (1,160 to 1,450 pounds per square inch) using the principle of sub-level caving. The coal then flowed in open channels to a feeding station where it was prepared for hydraulic hoisting. From the two mining areas the coal was pumped to the shaft by single-stage centrifugal pumps at a pressure of 25 bar (362.5 pounds per square inch). The coal slurry was delivered along 250-millimeter (10-inch) diameter pipes over distances of 2,900 and 2,200 meters (9,514 and 7,218 feet). At the shaft, a three-chamber pipe feeder pumped the coal slurry from a depth of 850 meters (2,790 feet) to the surface, at a pressure of 160 bar (2,320 pounds per square inch). The gross output of this system was 5,000 metric tons per day. The Hansa mine was closed because the overall operation was uneconomic. However, it did serve to show the feasibility of using hydraulic mining and transportation techniques.

A similarly radical departure from conventional mining techniques is being developed by the Chamber of Mines of South Africa for gold mining, involving primary beneficiation of the ore underground (see WORLD MINING, June 1981, pages 57 and 58). The removal of much of the waste rock before the ore is hoisted will obviously reduce the tonnages that have to be hoisted. There are many other ancillary advantages such as: improved support, by using the extracted waste as backfill; reduced timber costs due to this improved support; and reduced fire risk because of the use of less timber underground. Here, again, the pre-concentrate would be pumped to the surface.

The use of aluminum in cage and skip manufacture has also been proven to be energy saving (see WORLD MINING, November 1981, pages 46 and 47). All-aluminum man cages are already in use. In the future, much aluminum can be substituted for heavier materials in the construction of skips, which hoist ore and waste. In both of these cases, lighter conveyances can provide significant energy savings in hoisting costs. It has been shown that for every one-ton reduction of skip mass, there is a power saving of more than 100 kilowatts (134 horsepower).

When considering hoists themselves, a common principle to note is that power supply should not rely on the national grid. Most mines are not found near large power stations, but are often located at the end of a transmission line. This implies keeping peak power requirements as low as possible, consistent with the most efficient and economical operation. When considering energy costs, the friction hoist offers a significant advantage compared with a drum hoist. The friction hoist has a lower peak demand due to the use of tail ropes and subsequent balancing. Figures produced by Asea (Sweden) show that for a hoist operating at 11 meters per second (2,200 feet per minute) the root-mean-square power consumption for the drum hoist is 1,700 kilowatts, while for the friction


ABOVE, LHD's equipped with cable reel and electric power are becoming more widely used underground. Units like this M.A.N.-GHH LF4.1 save fuel and cut ventilation costs.



TROLLEY-ASSIST SYSTEM developed by General Electric (United States) has been successful in many operations. There are now plans to install it in a Zambian copper mine.

hoist it is only 1,000 kilowatts. At that time, the demand charge was assumed to be $3.50 per kilovolt-ampere per month, low by today's standards. However, using that figure, the added yearly operating cost of power for the drum hoist is $96,000.

At the developing No. 1 shaft of Western Deeps gold mine in South Africa, a 23-kilowatt generator set is to be installed. It will provide emergency power as well as allow the mine to provide some of its own power during peak demand periods. By doing this, the mine will be able to reduce its power costs and the generators should pay for themselves during the life of the mine. Similar generator sets are being installed at the Western Deeps Nos. 2 and 3 shafts, and at the neighboring Elandsrand gold mine. They will all be interconnected.

The energy efficiencies of hydraulic rockdrills are higher than pneumatic drills. The Chamber of Mines of South Africa, is once again conducting investigations on such drills in collaboration with Ingersoll-Rand. Excellent progress has been made in designing efficient hammer sections and in the use of water as the hydraulic fluid. The most difficult problem involved the rotation mechanism, necessitating the evolution of a new mechanism, the quadruple plunger rotation. Two prototypes are being evaluated. One of the main criteria being employed is that in solid quartzite, using 40-millimeter (1.6-inch) chisel bits, a drilling rate of 0.12-meter (0.39-foot) per minute should be achieved, per kilowatt of percussive power.

The small drill, weighing less than 30 kilograms (66 pounds), has a maximum percussive power output of 5 kilowatts (6.7 horsepower) and has achieved penetration rates in excess of 0.6-meter (2-foot) per minute when operated in a rig, at full power. On the average, penetration rates of 0.4-meter (1.3-foot) are being achieved when drilling into crushed stope faces. The small hydraulic drill achieves an average drilling rate of 15 holes per hour, and up to 20 has been attained. Pneumatic drills in the same faces produce about 10 holes per hour.

The large drill weighs some 75 kilograms (165.4 pounds) and has a maximum percussive power output of 10 kilowatts (13.4 horsepower). It has not yet been fully evaluated but an average penetration rate of 1.2 meters (3.9 feet) has been attained at full power, giving more than 30 holes per hour. Similar energy benefits have been achieved with hydraulic drill rigs in open pits. For example, a Böhler ETKD 11/35 has been operating in an Austrian mine for some 14 years. It is claimed that the energy costs for this electro-hydraulic rig are about 50 percent lower than for all-pneumatic rigs of the same capacity. At 2,000 operating hours per year this works out at a saving of over $3,000.

Cutting Haulage Costs

This has been the major trend in open pit mines. One of the most innovative techniques has been the development of trolley- assisted truck haulage. This technique retains the flexibility of truck haulage but the use of electrical, rather than Diesel, power allows major cost savings. It was first used by Riverside Cement Company in 1956 and subsequently used by other mines. Most recently, both Palabora Mining Co. Ltd. (see World Mining, July 1980, page 54) and the South African Iron and Steel Industrial Corporation, Ltd. (Iscor) (see World Mining, March 1981, pages 48 and 49) have implemented major trolley-assist systems.

Iscor, using trolley-assist for trucks of more than 150-ton capacity on upramps, has cut the hourly consumption of Diesel from 320 liters (84.5 gallons) to approximately 80 liters (2.1 gallons). Significant savings indeed, equivalent to about $6.70 per trip. In addition, the average speed on the ramp increased from about 12 kilometers (7.5 miles) per hour to 20 kilometers (12.4 miles) per hour. This technique has been met with a great deal of interest worldwide and a number of new projects are likely to be implemented. One certainty is a trolley assist system to be installed by General Electric at the Chingola open pit of Zambia Consolidated Copper Mines.

For those remaining with conventional Diesels, trends for the future will include multi-stage turbocharging, computerized engine control, and much greater use of aftercooling and intercooling. Engine manufacturers will be devoting more research to turbocompounding, extracting heat from exhaust gases, and using the energy to drive the vehicle. This involves reduced air intake temperature, to give both higher density and improved combustion. The on-board mini-computer can automatically time the engine to meet the demands of engine speed and load. Already electronically-controlled gearshifts are common.

Tire choice has been shown to make a significant difference to fuel consumption. During an investigation carried out by the Michelin Tyre Company, a Caterpillar 773 truck fitted with cross-ply tires used a total of 949 kilograms (2,093 pounds) of fuel over three test runs. Another 773, fitted with radial tires consumed 860 kilograms of fuel over the same three tests. A 9.38 percent fuel saving was achieved with the radial tires. Similarly, a rubber-tired loader fitted with cross-ply tires and filled with 30 liters (7.9 gallons) of fuel completed 1 hour 15 minutes of operation before running out of fuel. During this time, 93.5 cycles of a 40-meter (131-foot) haul were completed. The same unit fitted with radials ran for 1 hour 31 minutes, and completed 122.5 cycles. Therefore, fuel consumption with cross-ply tires was 24 liters (6.3 gallons) per hour compared to 19.8 liters (5.2 gallons) with radials.

Automatic truck dispatch systems, such as the ones used by Bougainville Copper Ltd. (see WORLD MINING, February 1980, pages 54 to 56) and Quebec Cartier Mining Company (see WORLD MINING, September 1981, pages 56 to 59), are another way of, indirectly, saving energy costs by increasing efficiency and productivity. Among the companies that offer the installation of such systems are Gould Inc. of the United States and Saab-Scania of Sweden.

Over recent years the hydraulic excavator, due to its selectivity, high breakout force, and maneuverability, has become increasingly popular as the loading unit in conventional shovel and truck operations. However, in the past, hydraulic shovels were only available with Diesel-power. This is another area where changes are being made. Electric power for the prime mover is now offered as an option by most manufacturers. This option is particularly cost effective with the larger machines, such as the O&K RH300 or the Poclain 1000CK. At the Letseng-la-Terai diamond mine in Lesotho, an electrically powered version of the Hitachi UH30, the UH30LE, is operating successfully, and fuel savings of up to 60 percent have been claimed. The unit is powered by two 132-kilowatt (177-horsepower), 3.3 kilovolt electric squirrel cage motors, and is fitted with a 3.7-cubic-meter (4.8-cubic-yard) rock bucket.

As with underground operations, conveyor haulage is always a major competitor to truck haulage. The operating costs of such installations are an interesting consideration. For example, Cable Belt claims the following for a system operating between the Eisenhower mine and the Twin Buttes Mill of Anamax Mining Company in Arizona, United States. Here, copper ore is transported at a rate of 2,000 tons per hour over a distance of 10 kilometers (6.2 miles) using 1,500 kilowatts (2,012 horsepower).

In New Caledonia, a stereoduc conveyor system, installed by Réalisation Equipments Industriels (see WORLD MINING, September 1980, pages 42 to 45), carries nickel ore over a distance of 13 kilometers (8 miles) on a tortuous route. Operating costs in 1979, when operating at only partial capacity, were 5.6 cents per ton kilometer (9 cents per ton mile). At higher capacities they should be less. Trucking costs under similar conditions were reported to be 27.8 cents per ton kilometer (44.7 cents per ton mile) at that time. True, these are both long-distance examples, but many open pit operators, under certain conditions, are finding that the loss of flexibility with conveyors is outweighed by the reduced operating costs when compared with trucks.

When considering transport over fairly long distances, another option is the aerial tramway. A cost comparison carried out by British Ropeway Engineering Company Ltd. involved the transport of limestone at a rate of 2,000,000 tons per year. The transport system would require an aerial tramway or conveyor installation 14.3 kilometers (8.9 miles) long, or a roadway haulage of 18 kilometers (11.2 miles). The operating costs per ton were calculated to be 73 cents for the tramway, 85 cents for the conveyor, and 235 cents for truck haulage. These are equivalent to 5.1, 5.9, and 130 cents per ton kilometer, respectively.

Interest in conveyors for open pit haulage is often, these days, associated with some form of in-pit crushing. Basically, three options are available: fixed installations, semi-mobile crushers, and mobile crushers. At the same Sishen iron ore mine where Iscor operates the trolley- assisted trucks, the company has in-

Poclain
400

ELECTRICALLY-POWERED hydraulic excavators offer significant fuel savings with little loss of flexibility. One such example, seen in action **ABOVE** is the Poclain 400CK.

stalled a semi-mobile gyratory crusher (manufactured by Krupp Industrie und Stahlbau), having a throughput of 6,000 tons per hour. In a theoretical example (see WORLD MINING, June 1981, pages 84 to 87), Krupp calculated that total operating costs for an all-truck operation were $6.64 per ton for ore and $8.40 for overburden. Using a combined system, utilizing trucks, conveyors, and semi-mobile crushers, the total operating costs fell to $2.74 per ton of ore and $7.28 per ton of overburden.

The Phosphate Development Corporation Ltd. (Foskor) has recently commissioned the world's largest mobile crusher at its Palabora mine in South Africa. This electrically powered unit should significantly reduce truck fuel consumption, which was some 104,000 liters (27,480 gallons) per month. The unit, capable of moving at 60 meters (197 feet) per hour, receives ore directly from an electric face shovel. After crushing to minus-250-millimeter (minus-10-inch), the ore is fed to an in-pit conveyor installation by the discharge conveyor. The crusher, manufactured by PHB-Weserhütte, has a throughput of 2,700 tons per hour.

But what of the so-called alternative energy sources: such renewable sources as solar, wind, geothermal, wave, or tidal? It is extremely unlikely that these will ever make a significant contribution to the total energy picture. However, in certain specific applications, some of these sources could be useful to the mining industry. Solar heating for water and buildings could serve to reduce the total overhead of a mining operation. Because of the nature of the industry, many mines are in isolated, windswept areas. Thus, as the technology develops, wind power could contribute in the future. Similarly, geothermal energy is a possible source for the mining industry. However, for now, the industry will, and must, concentrate on more conventional methods to reduce energy costs.

This is by no means an exhaustive review of energy saving ideas in the mining industry, but rather a review of the major developments in the field. Manufacturers of mining equipment and mine operators all over the world are involved in hundreds of projects aimed at beating the problem of increasing energy costs. ■

AERIAL TRAMWAY in Taiwan carries 420 metric tons of limestone an hour over 8.8 kilometers, with a vertical drop of 1,130 meters.

***Special Report:* ENERGY IN MINING**

Extensive trials with several machine types point the way to cost and energy savings plus improved working environment

Electric LHD's prove themselves at Boliden

The electric LHD has truly arrived. This month's cover picture shows the first unit in regular production operations (as distinct from trials) at a new Swedish mine specifically designed for electric LHD loading. This Wagner EST-5B unit in a production stope at Boliden Mineral's Hornträsk mine represents the culmination of a long test program, and the first step in a new era of trackless mining.

The reasons why this Swedish mining company sought to replace Diesel-powred LHD units with electrics will be paralelled in other mines in other countries.

At the beginning of the 1960's Boliden started using Diesel-powered LHD's in its mines. This permitted modification of the mining methods and created the conditions necessary for today's high degree of mechanization and productivity. Trackless LHD mining also meant that mining became safer, as the number accidents in conjunction with rock loading fell considerably.

The disadvantage of Diesel operation is that ventilation costs increase considerably. Because of the heat and fumes of the Diesel exhaust more air must be blown through the working sections to maintain healthy and tolerable conditions for the miners. For example, at Boliden's Udden mine in the Skellefteå district of North Sweden the capacity of the ventilation system is 200,000 cubic meters per hour. In other words, about 1,000,000 metric tons of air must be pumped through the mine each year. The mine produces about 350,000 tons of ore each year. The energy consumed by the fans, and the heating system for the air in winter, is about 6 gigawatt hours per year. This is very expensive. Calculations show it would be possible to reduce the ventilation requirements by fully half if the all-Diesel LHD fleet were to be replaced by electrically-powered machines.

Against this background Boliden started carrying out trials on the electrically-powered Toro 100 LHD in the middle of the 1970's. The Toro 100, manufactured by ARA in Finland, had a bucket volume of 1 cubic meter and was equipped with a 120-meter cable reel. Results from these trials were technically and economically favorable and the development of larger, electrically-powered machines was considered a matter of urgency.

Specifications for Electrics

In 1977 a poll was made among Swedish mining and construction companies who might be interested in electrically-powered LHD's. The answers were used to prepare a specification for an electrically-powered LHD. WORLD MINING reported this specification in the October 1977 issue—some of the main technical points were as follows:

- The cable length should be at least 150 meters, giving a one way operating range of 300 meters. If possible the cable length should be 200 to 250 meters.
- The machine should be capable, with full load, of climbing a 5 percent grade with a speed of at least 10 kilometers per hour.
- There is equal interest for two sizes of machine, one with a 6 to 7-ton capacity and one with a 10 to 12-ton capacity.
- The dumping height should be at least 2.5 meters.
- It should be possible to transport the machine without having it electrically connected at least 1,000 meters on a 15-percent gradient with a speed of 5 kilometers per hour. The transport could be carried out by towing or by using a Diesel-electric power pack.
- There should be no considerable increase in dimensions compared to an equivalent Diesel-powered unit.

This specification was sent to a great number of machine manufacturers lo-

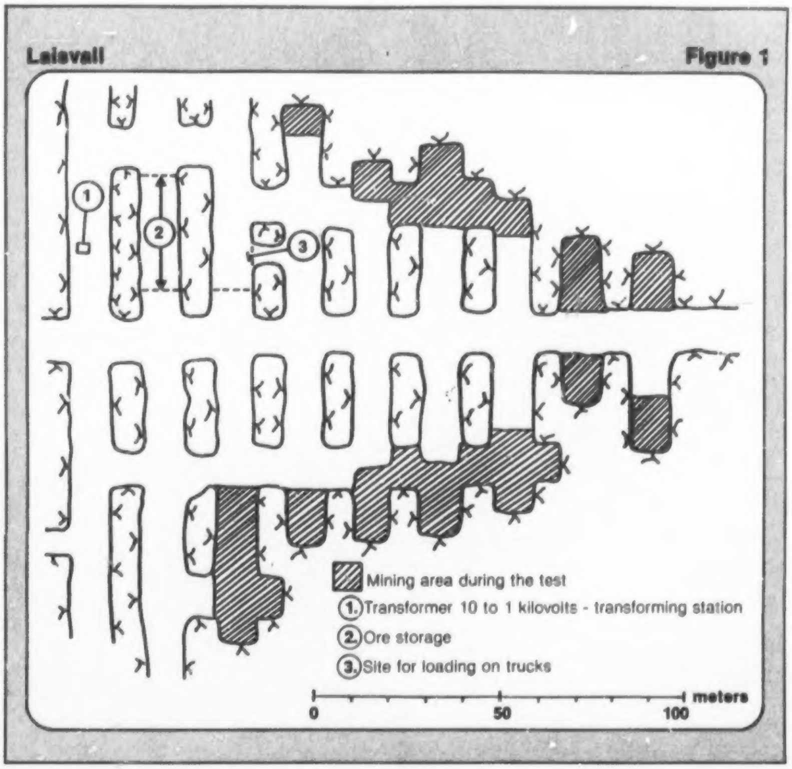

Laisvall

Figure 1

1
2
3
▨ Mining area during the test
① Transformer 10 to 1 kilovolts - transforming station
② Ore storage
③ Site for loading on trucks
0
50
100
meters

GHH LF 7.1E

WAGNER EST-5B

cated around the world. The challenge was taken up and a number of manufacturers offered to hire machines to be tested under realistic mining conditions.

The first large unit to be tested was the West German GHH LF 7.1E electric LHD. During the first six months of 1980 it underwent trials in the Laisvall mine, where room and pillar mining is employed. The project was carried out by Boliden in cooperation with the University of Luleå and LKAB, the Swedish state-owned iron ore mining company. Figure 1 shows the site used during the Laisvall trial where the machine loaded ore from a pile and transported it to an ore pass or to a truck.

The trials were then continued in even more realistic conditions in the Udden mine. This phase of testing was entirely under the control of Boliden. Udden is a cut and fill mine. Figure 2 shows the stope where the electric LHD was used mainly for loading and transporting ore to an ore pass.

During this test, time and motion studies were made to compare the capacity of the electric machine with Diesel LHD's and the results are shown in Figure 3.

The capacity of the electric machine was up to expectations. Indeed, the test confirmed experience gained elsewhere that electric LHD's have a slightly higher capacity than Diesel-engined units. This is due to the more powerful digging action, which fills the bucket better.

Experience showed that the operating cost per machine hour for an electric machine is slightly higher than for a Diesel unit of the same size (see Table 1).

Because of the better capacity shown above, the electrically-powered machine can be expected to incur approximately the same operating cost per ton transported as a Diesel-engined machine. It should be possible to reduce the cable costs by improved routines and development of better equipment for reeling-in the cable so that the operating costs per machine hour will be aproximately the same for both types of machines.

Electric LHD's thus already are demonstrated to have costs per ton loaded equal to Diesel units. The machines are still at a fairly early stage in their development so further cost reductions may be expected. This does not take into account the energy savings related to reduced ventilation requirements. Taken all together the interest of mines in electric LHD's is clear.

The tests at Laisvall and Udden gave an average energy consumption of 84 kilowatt hours per hour and 1.06 kilowatt hours per ton.

A key factor for any mining machine is reliability. This was carefully monitored by recording the type of fault and the operating hour meter reading when the fault occurred (see Table 2).

Boliden has noted that the number of hours spent on repairs (mechanical and electrical) per machine-hour up to the present has been slightly less than the average for Diesel-engined machines.

The great advantage of electrically-powered machines is that they do not generate exhaust fumes. At first this was looked at from a primarily environmental point of view. Latterly the great energy saving advantages have become more and more important. Another advantage is that they are less noisy than Diesel-engined machines. Measurement of the equivalent sound levels at the driver's seat gave 98 dB(A) on the electric LHD and 101 dB(A) on the Diesel machine.

Both machines were of the same size class and both were equipped with a protective canopy over the driver's seat. The noise from the electric machine is of a higher frequency and is thus easier to attenuate with ear protectors.

Boliden engineers say they are satisfied with the trials of electrically-powered machines. The miners like them, too. The engineers also point out that in their opinion electric machines are not yet fully-developed. This is not surprising. Areas where they see development need to be greatest are in cable reeling, transport between loading points and mine levels, and cable maintenance.

Despite the demands on flexibility

Table 1.
Comparative operating costs of electric versus Diesel LHD's

	Electric LHD	Diesel LHD
Relative cost	106	100
of which percentage components are:		
Driver's wages	41	43
Energy	5	14
Tires		
Service and maintenance Bucket Accidents and repairs	24	25
Cable	13	—
Cable reel	2	—
Other electrical repairs	3	—
Other repairs	12	18
	[illegible]	[illegible]

Table 2.
Reliability of electric LHD under trial

Type of faults	Number	Incidents per 1,000 hours
Hydraulic system	18	10.9
Cable and cable reel	4	2.4
Other mechanical faults	22	18.3
Other electrical faults	2	1.2
Totals	46	27.8

made in cut and fill mining, Boliden has found that electrically-powered loaders can often compete with Diesel-powered LHD's in these conditions. When methods of mining employing permanent loading points are introduced the electric loaders give great advantages.

Of course, it is not practicable to completely replace Diesel-engined machines underground by cable reel electric machines—mainly for reasons of limited range—but with the correct mine design and layout this limitation can in fact be controlled.

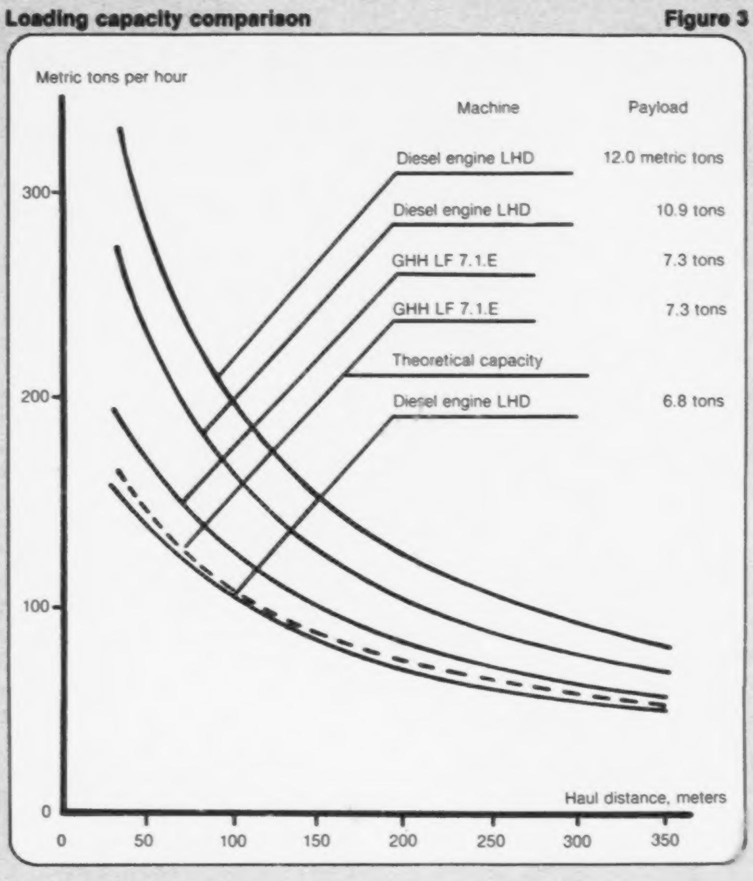
The proof of the pudding is in the eating and Boliden appears to like the taste of electric LHD's because the test program has now expanded to three mines. At Udden GHH LF 7E is being used, at Garpenberg North in central Sweden an electric Toro 350E is showing its paces, and in the newest development, the Wagner ST5 E is loading in Horntrask, Boliden's first all-electric, all-hydraulic mine.

Furthermore, at the time of WORLD MINING's visit to Boliden in February, larger electric LHD's (the GHH LF 12, with a tramming capacity of 12,000 kilograms and a 6.0-cubic meter bucket, and the Wagner EST-8A with a 10,866-kilogram tramming capacity and a 6.1-cubic meter bucket) were on order and expected to go into the mines in spring or early summer.

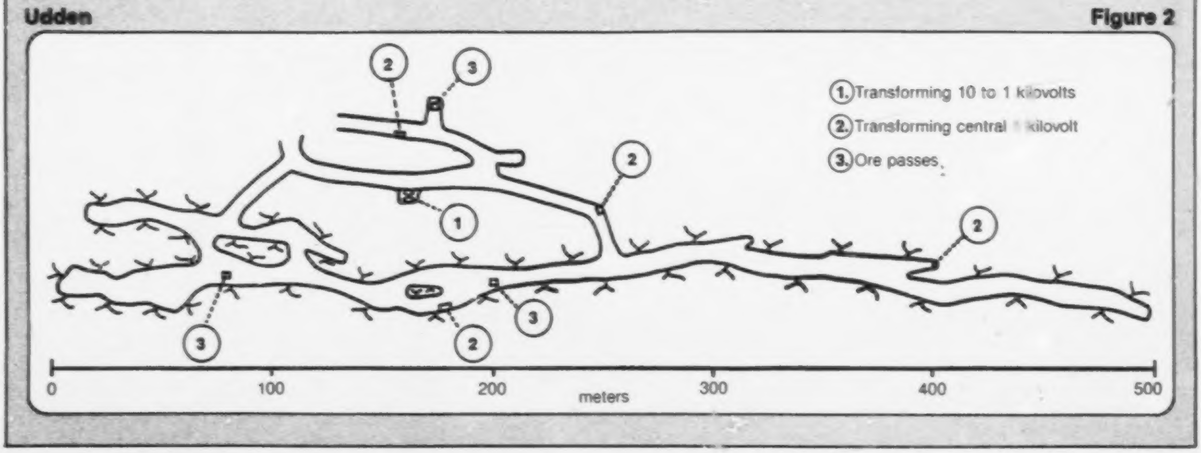
From the tests conducted so far, Boliden has shown that electric LHD's can compete favorably with Diesel units in existing mining conditions. However, if a mine or level is designed from the start taking electrics into account, then their operating and cost advantages over Diesels will be very great indeed.

This is why the Hornträsk experiment is important. Although a small mine, it is the first that has been planned from the start with electric loading (and all hydraulic drilling) in mind. The total ore loading is handled by the Wagner EST-5B in conditions that take the fullest advantage of the electric LHD's unique capabilities. Electric LHD's can show a good account of themselves in cost and production capacity in existing mine conditions designed for Diesels. The Hornträsk results will show what they can do in a true all-electric mine. ■

Loading capacity comparison **Figure 3**



Udden **Figure 2**


① Transforming 10 to 1 kilovolts
② Transforming central 1 kilovolt
③ Ore passes
1
2
3
0
100
200
300
400
500
meters

Special Report: **ENERGY IN MINING**

The first step in any energy reduction program should be to determine just how much energy is currently being consumed. Here is an example of how this can be done for a hypothetical open pit mine

Energy consumption at the Big Burgher mine

By **Dan Nillson, Art Ettlinger, and Karl Burgher**
Department of Mining Engineering
Michigan Technological University

Mining means drilling and blasting to break down the rock, and loading and haulage to bring the ore to a crusher and the waste to a storage place. Increasing energy costs have become a critical factor in the profitability for many mining ventures.

The Office of Surface Mining, United States Department of the Interior, now sponsors a research project at Michigan Technological University titled, "The Effect of Increasing Energy Costs on the Future Relation Between Open Pit or Underground Mining".

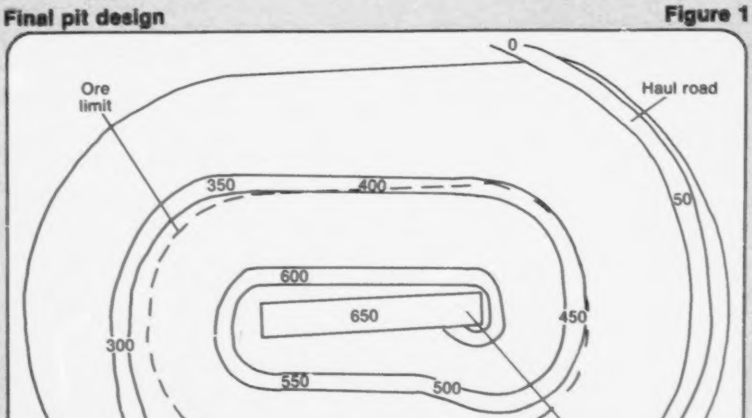
To learn more about the energy consumption pattern in different types of mining operations, hypothetical deposits have been studied as part of this program. In this article, the energy consumption in a large hypothetical open pit mine, which has been called the Big Burgher mine, is evaluated. The fifth year of ore mining will be examined.

Energy Use Measure

Two measures of energy use are normally used in the literature. The first, termed useful energy, or net energy, represents the direct theoretical heat value of the fuels and purchased electricity used. Gross energy differs only in that it includes the heat losses incurred by electric utilities in the process of generating the power. The gross measure takes into account both direct and indirect calls upon energy resources by mining, at least insofar as electricity is concerned.

A more complete measure of gross energy demand would have taken into account other conversion and transmission losses; one of these is the transmission loss in natural gas.

Final pit design **Figure 1**



While the gross energy measure is helpful in indicating the impact of an industry on total energy use, it is not a good indicator of the effects on energy use brought about by changes within the industry.

The net energy measure more accurately reflects technological developments as well as changes in production process and product mix on energy use over time. Yet it creates distortions if the industry generates part of its electricity internally and the proportion changes over time. Such a development can affect the net energy measure to a significant degree.

According to the Statistical Yearbook from the Edison Electric Institute, the whole United States electric utility industry used 10,470 Btu's per kilowatt hour in 1979. Since there theoretically are 3,412 Btu's per kilowatt hour, only 33 percent of the energy content in purchased fuels could really be used. Thus, a decrease in fuel consumption in the mineral industry with a corresponding increase in purchased electric energy should result in a lower Btu figure to the extent that conversion losses are shifted to a public utility.

In a study of the gross energy consumption, a conversion factor of 10,470 Btu's per kilowatt hour should be used, while in a study of the consumption of useful energy, a factor of 3,412 Btu's per kilowatt hour should be used. Since this study is mainly concerned with technological developments and changes in mining techiques, it is best to use the "net energy" approach. All figures in this report therefore represent net energy unless otherwise stated.

Energy mixes for underground mines differ substantially from those for open pits. Open pit mining mainly uses Diesel fuels, while underground mining to a larger extent depends on electricity. A gross energy measure should therefore give a more pessimistic picture of underground mining than a net approach. This is especially disastrous if one considers that electricity is produced from domestic coal and Diesel fuel to a large extent from imported oil.

No decision is based solely on energy consumption. Even if energy conservation is an important task, the overall economy is the main objective in any mining venture. Energy losses in supplying power to the mineral industry, be it gas, electricity, or refined petroleum products, are taken into account in the different prices the consumer has to pay for different types of energy. This further strengthens the conclusion that a net energy measure must be used here.

It is appreciated when examining a problem of this type that energy costs may be both direct, in terms of an increased fuel bill, as well as indirect, in terms of such items as raw materials and labor. These latter factors lie outside the scope of this investigation, as it is the purpose of this report to examine only the effects of increases in direct fuel cost. It is believed the indirect costs will be accounted for mainly in an overall inflation factor, which will force a general rise in the price of all commodities, labor, and manufactured goods.

Deposit and Mining Plans

This porphyry copper deposit can be simplified to a flat, tabular ore body lying 100 meters (327 feet) below the surface. It contains 0.5 percent copper and has an area of approximately 1,000,000 square meters (0.38 square mile). Within the ore zone, 65 percent is actually ore and 35 percent is waste that must be hauled to a dump.

It is assumed that the deposit will be mined with open pit methods to a final depth of 650 meters. The final pit design is shown in Figure 1. A total of 1,550,000,000 short tons of waste and 750,000,000 tons of ore can be mined with the planned ultimate pit limits.

Table 1.
Energy consumption for drilling

Parameters	Values
Spacing	9.1 by 10.0 meters
Bench height	12.2 meters
Hole diameter	15 inches
Density	3 tons per cubic meter
Tons per hole	3,330 tons
Penetration rate	1 foot per minute
Penetration time	70 percent of running time
Energy use	375 kilowatts per hour[1]
Results	**Values**
Mine production	81,000,000 tons
Number of holes	24,340
Energy demand	8,600,000 kilowatt hours
Per ton of rock	0.11 kilowatt hour
Per ton of ore	0.34 kilowatt hour

Calculations based on information from Gardner-Denver.

1. Using an electrically-driven blasthole drill.

The annual ore production is assumed to be 25,000,000 tons. Figure 2 shows the pit after five years of mining. Before mining started, stripping operations had been underway for about two years. The figure illustrates that mining takes place on many different benches at the same time. Space is left on each bench to allow truck driving, which results in a low effective working slope angle. The final haulage road has only reached to a depth of 60 meters. There are also a number of temporary local haul roads.

During the fifth year, the amount of waste to be removed totals 56,000,000 tons, resulting in a total amount of 81,000,000 tons of material. The blasted waste and ore will be hauled to the surface by Diesel trucks. At a later date, it may prove to be profitable to construct a conveyor or skip hoisting system.

Drilling and Blasting

The calculations of the energy consumption for drilling are in Table 1. They are based on information provided by Gardner Denver. In Table 2, the cal-

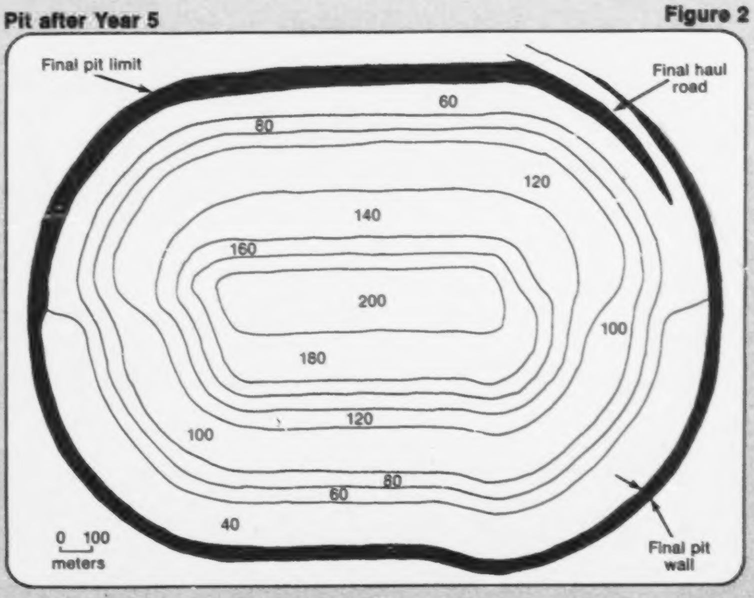
Table 2.
Energy content in explosives needed

Parameters	Values
Powder factor	0.40 pound per short ton of rock
Of which	60 percent ANFO by tonnage[1]
	40 percent slurry by tonnage[2]
Energy content:	
ANFO	433 kilocalories per pound
Slurry	400 kilocalories per pound
Results	**Values**
Mine production	81,000,000 tons
Explosive used:	
Slurry	13,000,000 pounds
ANFO	19,400,000 pounds
Energy content:	
Slurry	5,183,000,000 kilocalories
ANFO	8,417,000,000 kilocalories
Total	13,600,000,000 kilocalories
Total equals	15,800,000 kilowatt hours
Per ton of rock	0.20 kilowatt hour
Per ton of ore	0.63 kilowatt hour

Based on information from Treco Chemicals

1. Equals 0.24 pound per ton
2. Equals 0.16 pound per ton

Pit after Year 5 **Figure 2**



culations of the energy content in explosives needed are shown. These calculations are based on information provided by Ireco Chemicals.

Loading

In the following analysis, 120-ton electric drive trucks will be assumed. The rock at the working faces will be loaded into the trucks by 16-cubic yard (12.24-cubic meter) electric shovels. The calculation of the number of loaders and trucks needed is based on information provided by Wabco.

The material density is 3 tons per cubic meter; this is the in-situ density of the material. After blasting, the rock will expand to give 2.2 tons per loose cubic meter, using a swell factor of 0.74.

The bucket fill factor is 0.90; this is a measure of the bucket's ability to obtain its rated capacity. It is related to material characteristics of the rock and to the bucket size. The value will typically be in the range of 0.85 to 1.00.

The cycle time per pass is 40 seconds, the time it takes for one complete loading cycle of the shovel. This depends on bucket size, shovel design, material hardness, etc. Thus, to determine the number passes that are required:

Load per pass (L/P) = Material density x fill factor x bucket size
= 2.2 tons per loose cubic meter x 0.90 x 12.24 cubic meters
=24.5 tons

Number of passes to load truck (N)
= Truck rating ÷ L/P
= 120 ÷ 24.5
= 4.9, use 5 passes

A whole number of full bucket swings should be used, so that the final payload is as close to rated truck capacity as possible without exceeding 10 percent of the rated capacity.

Payload per trip (P) = L/P x N
= 24.5 x 5
= 122.5 tons, 10 percent overload is not exceeded

Load time, (T) = N x cycle time per pass
= 5 x 40 seconds
= 200 seconds ÷ 60 seconds per minute
= 3.3

The spot time is 21 seconds; this is the time it takes for the truck to maneuver itself to the shovel.

It is now possible to calculate the capacities for the shovels. It will be assumed that 50 minutes can be used in one hour. The number of shovels and shovel-hours shown in Table 3 include a 75 percent utilization factor. Utilization refers to a machine's actual percentage of use. A machine may not be working due to maintenance and mechanical difficulties, driver slackness, reduced production, queuing situations, etc. The calculation assumes a working time of 1,000 shifts per year.

In a real mine it is important to look upon loading and haulage as one system and check that the capacities for shovels and trucks really match each other. That picture will be different on different benches in our hypothetical mine. The figures shown therefore represent average values.

The total number of shovel-hours can now be calculated as well as the energy-consumption. The average energy-consumption for a shovel of this size averages some 500 kilowatts per hour.

The number of trucks one shovel theoretically can handle can be found by dividing the total cycle-time for a truck with the load-time and the spot-time (see Table 4).

Haulage

The cycle time is needed to determine the production rate of a truck. It is the time required for a truck to make one round trip. This total time is usually broken down into two main groups: "fixed time" and "variable time".

The "fixed time" consists of the load and spot time as described above, and the "turn and dump" time.

Turn and dump time is 1.0 minute as an average suggested by Wabco. This is the time needed to raise and lower the truck body plus maneuver at the dump point. Depending on truck design, it will

Cross section **Figure 3**

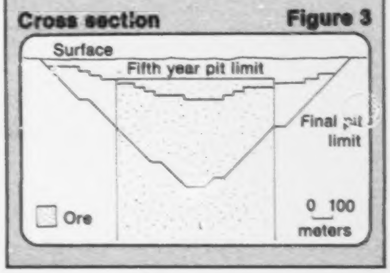


Table 3.
Shovel capacity

	Ore	Waste
Tons	25,000,000	56,000,000
Capacity[1]	1,678	1,678
Capacity[2]	10,000,000	10,000,000
Number of shovels	3 (2.5)	6 (5.6)

1. Tons per hour. 2. Tons per year

Table 4.
Number of trucks per shovel

	Ore	Waste
Cycle time per truck, minutes	20.73	18.71
Load and spot time for shovel, minutes	3.65	3.65
Number or trucks per shovel	5.7	5.1

Table 5.
Average speed of haulage trucks[1]

Year 5	Level haul	Downhill	Uphill
Empty	52.0 (32.3)	21.7 (13.5)	—
Loaded	39.2 (24.3)	—	8.4 (5.2)

Table 6.
Total cycle times

	Minutes	
	Ore	Waste
Load time	3.3	3.3
Spot time	0.35	0.35
Turn and dump	1.0	1.0
Haulage	19.25	15.90
Total	23.90	20.55

Table 7.
Trips and capacities

	Ore	Waste
Cycle time	23.90	20.55
Minutes per hour	50	50
Trips per hour	2.09	2.43
Tons per hour	256	298

Table 8.
Trucks and truck-hours

	Ore	Waste
Mine production[1]	25,000,000	56,000,000
Capacity per truck[1]	1,540,000	1,790,000
Number or trucks	17	32
Truck-hours	97,400	187,700

1. tons

take from 12 to 20 seconds to raise the body, and about half that time to lower it, the remainder of the 1.0 minute being maneuvering time. Total fixed time is 4.65 minutes.

Variable times: This includes a haul time and a return time. The haul time is the actual time spent by the truck hauling rock from the working face to a dump or crusher. Return time is the time required for the empty truck to return to the working face for a new load. Generally, the return time is shorter than the haul time.

To determine the haul and return times, the speed of the truck must be known. This will depend on the total resistance encountered by the truck, gross vehicle weight, and other factors, including acceleration, deceleration, operator skill, road curves, and other safety considerations.

In addition to truck speed, the distance between the working face and the dump or crusher must be known. The same route is taken by trucks going to or coming from the dump point. This distance will depend on the production plan at that point in time. The distance along the grade will depend on which bench the ore is waste is being from. There will be a distance travelled by the trucks before it enters the grade and after it leaves the grade. It will be considered constant throughout the mine life. These separate distances, or segments, make up the "haul profile".

Haulage times on the ramp are flexible times and will change with the production plan. The distances used in arriving at the travel time on the ramp were determined by the bench the ore or waste was being removed from. When multiple benches were being mined, as was the case, a weighted average in terms of total tonnage was taken. During the fifth year the haul distance for ore is 1,795 meters one way and for waste 1,000 meters one way.

Truck speed: Maximum speeds along adverse grades can be found from the truck's performance chart. For favorable, or downhill grades, the maximum speed can be obtained from the truck's dynamic retarding chart. Both these charts are supplied by the manufacturer, and give an ideal or maximum speed for a given total resistance and gross vehicle weight.

Once the maximum truck speeds are found from the performance charts, they must be converted to an average speed. This will give a reasonable indication of the true speed a truck can reach, based on haulage distance, and whether the truck is accelerating or decelerating, or maintaining a constant speed through the haulage segment. Speeds realized by the haulage trucks, based on the above calculation as applied to conditions at Big Burgher Mine during the fifth year of ore production, are presented in Table 5.

It is now possible to calculate the total cycle times, shown in Table 6. With the cycle times available, it is possible to calculate the number of trips and capacities per hour (see Table 7). The number of trucks and truck-hours can now be found. These figures, shown in Table 8, include a 75 percent equipment utilization factor and the same working time as for as the shovels, 1,000 shifts per year.

Diesel Consumption of Trucks

There are two basic procedures to estimate fuel consumption. The most accurate is to match the engines' fuel curve, from the engine's performance chart, with the performance over a given haul profile. This can become very involved and must be by computer increment analysis. A simpler method is to calculate fuel consumption through load factors. The fuel consumption at rated gross horsepower and maximum engine revolutions per minute is multiplied by a load factor. These factors are dependent on difficulty of operation and amount of time spent at full rated horsepower. They will vary with loading and truck model. Load factors to use as an average, suggested by Euclid Inc., are: high, 40 percent; average, 33 percent; and low, 25 percent.

The engine performance chart for a Cummins Diesel engine model KTA-2300-X, the type used in 120-ton Wabco trucks, has been studied. The fuel consumption at maximum engine revolutions per minute is 0.372 pound per horsepower hour; thus, the gallons per hour consumed is:

0.372 pound per horsepower hour x
1,200 horsepower
=446.4 pounds ÷
7.12 pounds per gallon
= 62.7 gallons
per hour

Applying the load factors to this value will give a range of 16 to 25 gallons per

Energy use breakdown **Figure 4**

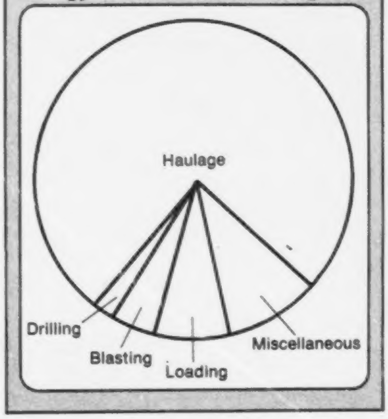


Table 9.
Fuel consumption

Ramp distance[1]	Gallons per hour
0-2,100	25
2,101-3,000	28
3,001-3,500	32
3,501-4,500	33
4,501-5,500	35

1. meters

Table 10.
Fuel consumption, Year 5

	Average haul distance[1]	Gallons per hour	Truck-hours	Gallons consumed
Ore	1,795	25	97,400	2,400,000
Waste	1,000[2]	25	187,000	4,700,000
Total				7,100,000

1. meters 2. one way

Table 11.
Total energy consumption

Function	Kilowatt hours	Kilowatt hours per ton of rock	Kilowatt hours per ton of ore	Percent
Drilling	8,600,000	0.11	0.34	2.0
Blasting	15,800,000	0.20	0.61	4.0
Loading	24,300,000	0.30	1.00	7.0
Haulage	297,500,000	3.65	11.90	77.0
Miscellaneous	38,800,000	0.49	1.55	10.0
Total	385,000,000	4.75	15.40	100.0

hour. As will be seen later in this section, these values tend be a little conservative and will be increased for use in Big Burgher Mine.

As a check on the fuel consumption calculated using load factors, they were compared with several fuel consumption analyses prepared by Wabco. These analyses were arrived at using the computer increment procedure previously mentioned. In the Wabco analysis specific haul profiles were used. These profiles do not match exactly with those encountered at Big Burgher. They are close enough to the Big Burgher profiles that an average fuel consumption from a particular profile can be used. Table 9 shows the values of gallons per hour fuel consumed chosen for use in the Big Burgher mine.

Yearly Fuel Consumption

The total truck hours per year, for ore and waste, can be used to arrive at the total gallons of Diesel fuel per year consumed at Big Burgher mine. The gallons per hour previously determined multiplied by the total truck hours per year for ore and waste will yield the yearly fuel consumption. These values for ore and waste are presented in Table 10,along with the total fuel consumed during the fifth year.

With 41.9 kilowatt-hours per gallon, the kilowatt hour equivalent can be found:

7,100,000 gallons x 41.9 kilowatt hours per gallon
= 297,500,000 kilowatt hours

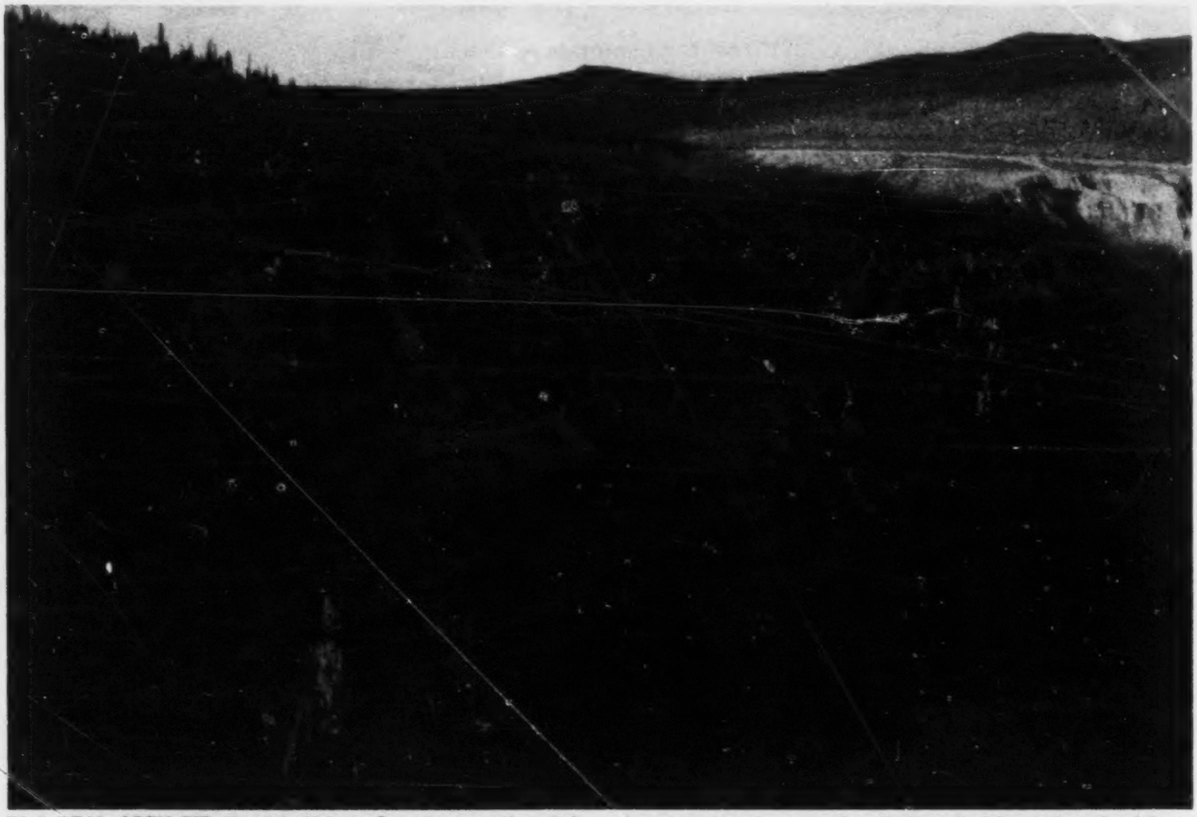
Energy is also needed for water pumping, lighting, heating of workshops, offices, and for different service vehicles. No study has been performed on this aspect. The amount of energy spent on water-pumping in particular can vary considerably between different mines. However, previous experience has shown it is enough to add 10 percent for miscellaneous energy-consumption in the Big Burgher mine, which means 38,800,000 kilowatt hours.

Total Energy Consumption

The energy consumption for the different activities are added in Table 11. The table shows that haulage of the rock to the surface is the most energy-consuming activity in the mine and accounts for 77 percent of the total energy requirement, which is 4.75 kilowatt hours per ton of rock corresponding to 15.6 killowatt hours per ton of ore mined.

The Diesel fuel used for haulage thus accounts for 77 percent of the total energy requirement.

The calculated energy consumption can be compared with a figure presented by the U. S. Bureau of Mines for United States open pit copper mines in 1973 (Informational Circular 8699). According to that study, the energy consumption was 5.2 kilowatt hours per ton of rock handled. It is, of course, difficult to compare different mines. However, in our mine we have probably used larger and more energy efficient equipment than was used in 1973. It is also probable that the last years' increased prices for Diesel have resulted in a lower energy consumption today than in 1973. But since fuel consumption for the trucks accounts for such a large part of the total energy requirements, a minor change in the haul-distance would result in a considerable change. ■



IN A REAL OPEN PIT, like this Yukon, Canada operation, it is important to look upon loading and haulage as one system, and it is also necessary to remember that no decision is based solely on energy consumption. Rather, a net energy measure must be used.

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World Mining

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THE COVER

The faces of Southeast Asian mining are many, ranging from small, independent tin dredgers to some of the largest copper operations in the world. This month, WORLD MINING takes an in-depth look at this important region. *Photograph by Malaysian Mining Corporation.*

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Special Issue: SOUTHEAST ASIA

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Some $5,400,000,000 in capital spending is planned in the near future in Southeast Asia. WORLD MINING takes a look at the region in the entire feature section of this month's Special Issue

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John Chadwick says that Natai Jetty, north of Phuket, is the most interesting mining area he has ever visited. The illegal offshore tin miners of past days have now been given a mining area of their own. This report covers the small dredge operations, and also looks at one of the major mining operations in the area

Gopeng Consolidated 46

This mine, near Ipoh, Malaysia, has always been known as the largest gravel pump mine in the world. Chadwick found that this is no longer strictly true—Gopeng has in fact largely moved away from conventional hydraulic mining to earthmoving techniques

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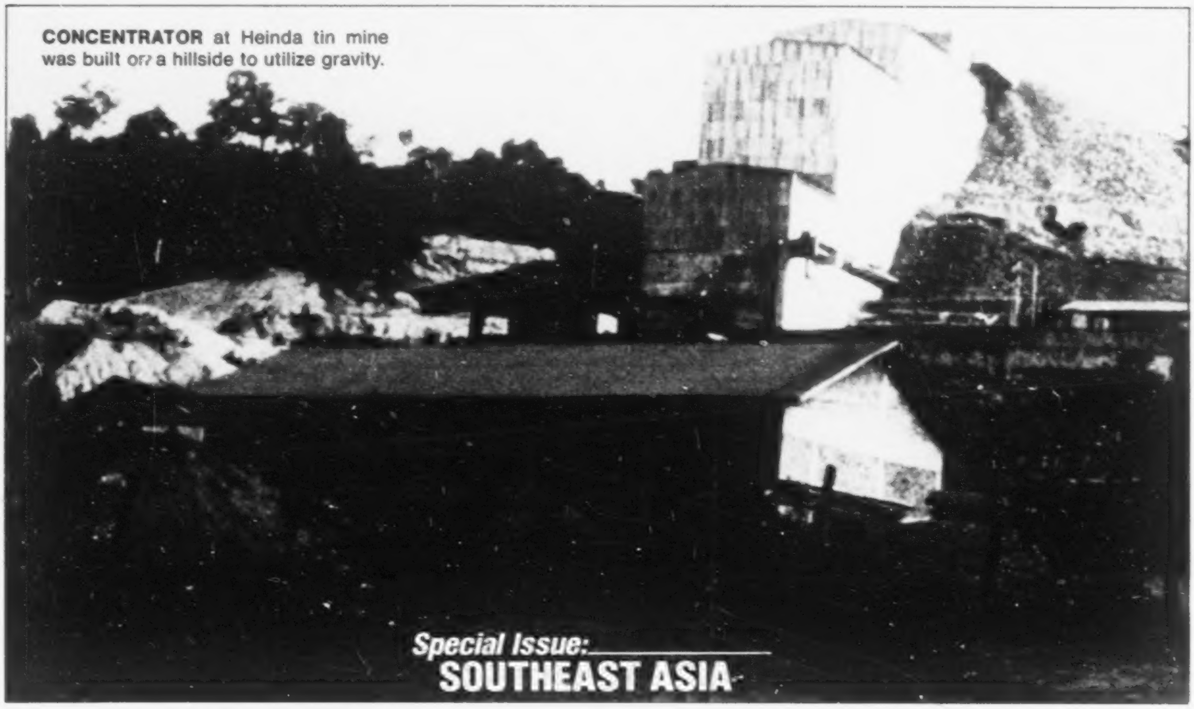

CONCENTRATOR at Heinda tin mine was built on a hillside to utilize gravity.

Special Issue:
SOUTHEAST ASIA

The country has great potential for future mineral production if past poor levels of exploration are stepped up

Burma—high level of unrealized mineral potential

By **John R. Chadwick**
Associate Editor

In 1939, Burma's output of refined lead, tin concentrate, tungsten concentrate, combined tin-tungsten concentrate, and silver was 76,590 tons, 5,964 tons, 7,824 tons, 5,564 tons, and 193,779 kilograms (6,230,000 ounces), respectively. By 1980 these levels had fallen to 5,863 tons of lead, 881 tons of tin, 595 tons of tungsten, 1,837 tons of combined concentrate, and 12,535 kilograms (403,000 ounces) of silver. These dramatic figures represent production declines of 92.3 percent, 85.2 percent, 92.4 percent, 67 percent, and 93.5 percent, respectively. The problem is not only one of failing reserves, but also insufficient prospecting and development during the ensuing decades.

There are many areas of undeveloped resources: primary, alluvial, eluvial, and offshore deposits of tin and tungsten, with some fluorite, on the southern part of the Shan Plateau and in the Tenasserim districts, in the southeast part of the country near the border with Thailand. The Shan Plateau, an area of base metal mineralization, contains lead, zinc, silver, and copper. Porphyry copper mineralization exists in the Tertiary volcanic arc of the Pegu Yoma, in Central Province. Antimony occurs on the Shan Plateau and in the north of the Tenasserim districts. Nickel, chromium, base metal, and platinoid mineralization are associated with the Ophiolites in Western Province. Finally, coal deposits are found in the Tertiary basins of Central Province and on the Shan Plateau. Also, major areas of this 678,030-square kilometer (261,720-square mile) country remain essentially unmapped and, from a geological point of view, unknown.

Lead-Zinc-Silver Potential

The country's major mine is the Bawdwin mine, which currently produces about 6,000 metric tons each of lead and zinc, and over 12,450 kilograms (400,000 ounces) of silver per year. Operated by the No. 1 Mining Corporation, it was once one of the world's great mines, with a history stretching back to the 11th century. Its decline in production results from depleted high grade reserves. Recent work here has been aimed at developing low-cost open pit mining methods to economically recover low grade ore. The latest reserves, suitable for open pit mining, were estimated at 30,000,000 tons assaying 3.5 percent Pb and 60 to 90 grams (1.9 to 2.9 ounces) Ag per ton. Chalcopyrite also occurs irregularly throughout the deposit.

Another mine, Yadana Theingi, 80 kilometers (50 miles) northeast of Maymyo, was developed during the last decade. The ore is reported to have a high silver content. The last recorded production figure was 804 tons of lead concentrate in 1972. At about the same time, it was reported that the Bawsaing mine had been re-examined. Production was planned at a rate of 800 tons of sulphide ore, 1,000 tons of lead carbonate ore, and 1,000 tons of lead slag per year. A promising zinc carbonate deposit is the Longh Keng, some 220 kilometers (137 miles) southeast of Mandalay, reported to contain some 1,000,000 tons of smithsonite. Lead, zinc, and silver occurrences in narrow galena veins in limestone are common. Although generally reported to be small, the deposits may indicate a Mississippi Valley-type mineralization.

Tin and Tungsten

These are the major mineral deposits of Burma, where there are almost 600 recorded workings. The two occur in both lode and detrital deposits; the alluvials carry tin, as cassiterite only. The narrow tin belt in Burma is an extension of the Banka-Billiton-West Malaysia-Thailand belt, which stretches a distance of some 1,200 kilometers (750 miles) from Victoria Point, in the south, northward to near Mandalay. The whole stanniferous, metallogenic province stretches for 3,000 kilometers (1,865 miles).

Mawchi mine was, at one time, the second largest lode tin mine and the largest individual tungsten producer in the world. The tin to tungsten ratio in the ore is about two to one. In 1970, the reserves at the mine were calculated to be 831,000 tons of mineable ore assaying 0.97 percent Sn and 0.52 percent WO_3.

Heinda mine, some 40 kilometers (24 miles) east of Tavoy, is an alluvial tin mine. Toward the end of the 1970's, expansion was undertaken to increase annual tin concentrate production to 1,000 tons. In 1977, mineable reserves were estimated to be over 19,000,000 cubic meters (25,000,000 cubic yards) with a cassiterite content of 0.69 kilogram per cubic meter (1.16 pounds per cubic yard). This was originally a gravel pump mine but the peculiar nature of the deposit, with cassiterite occurring in consolidated conglomerates, led to a change to conventional open pit mining techniques. Gravel pump mining left large boulders that hampered operations. The consolidated ore requires drilling and blasting for truly effective mining.

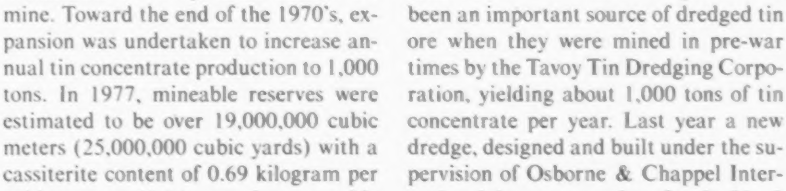
Like the other countries in this metallogenic province, small mines (mainly gravel pump operations run by Chinese) play an important role in total tin production. In 1980 it was reported that five new small mines had opened in Tenasserim, substantially raising tin-tungsten concentrate output. Contained tin production in 1980 totalled 1,100 tons.

Kanbauk, 92 kilometers (57 miles) north of Tavoy, is a mine with potential for the future. At the end of the 1970's, it was producing at a rate of 200 to 300 tons of tin-tungsten concentrate per year. Other primary quartz vein deposits found in Tenasserim include: Hermyingyi, Widnes, Yadanabon, Steel's Paungdaw, Kalonta, Pagaye, and Taungpila. Hermyingyi, 40 kilometers (25 miles) northeast of Tavoy, has 306 separate veins. Production towards the end of the 1970's was around 150 tons of tin-tungsten concentrate per year. Yadanabon, in the southern part of the Tenasserim, is primarily a tungsten mine. Its production at that same time was less than 150 tons of tungsten concentrate per year. In all, 77 ore veins are known here.

The Heinze River basin, a drowned tidal valley, has attracted a good deal of attention in recent years. A number of loans were negotiated with a view to expanding and restoring production in this area. These underwater deposits had been an important source of dredged tin ore when they were mined in pre-war times by the Tavoy Tin Dredging Corporation, yielding about 1,000 tons of tin concentrate per year. Last year a new dredge, designed and built under the supervision of Osborne & Chappel International, began operations for the No. 2 Mining Corporation. This was the first dredge to be built for operation in Burma for many years. It has a rated capacity of 378 cubic meters (494 cubic yards) per hour. Expansion of the operations in the Heinze basin is also likely to lead to the construction of a central concentrator in Tavoy to beneficiate tin, tungsten, and scheelite ores.

Offshore tin dredging possibilities have largely been ignored up to now. However, the major reserves found around the Phuket area in Thailand (see page 42), coupled with the known, rich onshore deposits in Tenasserim, suggest that the area off the Tenasserim Coast, the west coast of Burma, could be a good prospect. Exploration, with assistance from the United Nations Development Project (UNDP), has been underway in this area since 1975. In fact, this work has revealed tin and tungsten deposits offshore in the Gulf of Martaban.

Stibnite occurrences are narrow fissure fillings or scattered pockets in metamorphic rocks. Over 30 antimony deposits have been reported, chiefly in the Shan States and northern Tenasserim. Important ones have been found at Libyin, Mong Seng, Naking, Thabyu, and Tele Chaung. Contained antimony metal production in 1980 was 440 tons.



DREDGE, designed by Osborne and Chappel for the Heinze River basin operation of the No. 2 Mining Corporation, has a rated capacity of 378 cubic meters (494 cubic yards) per hour.

Copper Prospects

There are more than 20 other reported occurrences of copper in the country. Most important is the development of the Monywa porphyry deposits, some 105 kilometers (65 miles) west of Mandalay. There are three separate deposits: Sabetaung, with 11,300,000 tons at 1.5 percent Cu; Kyizintaung, 7,800,000 tons at 1.4 percent Cu; and Letpadaungtaung, 7,900,000 tons at 1.3 percent Cu. Recently published figures of total reserves have ranged from 70,000,000 tons to 200,000,000 tons at 0.78 percent Cu.

An open pit mine has been established with a planned output of 12,000 tons of ore per day. The ore is fed to a copper flotation concentrator at Salingyi. The capacity of this plant is 60,000 tons of concentrate per year. Lurgi has submitted plans to the No. 1 Mining Corporation to construct a smelter. The Kalewa coal deposits, to the northwest of Monywa, are important to this development. There are reported to be over 100,000,000 tons of coal here.

Two known nickel deposits occur, in close association with serpentinite, in the northern Chin Hills. By far the largest is at Mwetaung, about 27 kilometers (17 miles) northwest of Kalemyo. Possible reserves are estimated to be 110,000,000 tons at a grade of just over 1 percent. The smaller deposit is at Tagaungtaung, with possible reserves of 1,300,000 tons at a grade of 1.5 to 2.0 percent.

There are about 20 known iron ore showings but only the Pang Pet deposit, in Shan States, has been developed. Proven ore reserves are reported to be 70,000,000 tons of 42 to 56 percent Fe.

Primary and alluvial gold mineralizations occur throughout Burma. Primary gold was mined at Kyaukpazat until the turn of the century. There is also primary gold at Shweminbon. Alluvial gold has been recovered from the Upper and Lower Chindwin, the Sittang, the Uyu, and the Upper Irrawaddy rivers.

Gemstones

Burma is famous for its gemstones, particularly rubies and jade. The best known locality for rubies and sapphires is the Mogok-Kyat-Pyin area; the Tawmaw-Hpakan area in the northern state of Kachin is noted for jade. Mogok is the center of the gem mining industry. The rubies and sapphires occur in two forms: as primary minerals in marbles; or as derived minerals in alluvial muds and gravels. The jade also occurs in two forms: as dikes in serpentinite (for example at Tawmaw); or as boulders in river deposits, such as at Hpakan. Kamaing, in this same area, is the only source of so-called Imperial Jade in the world. Imperial Jade is a semi-transparent variety of jadeite, closely approximating gem emerald in color. Spinels are also found with the jade and sapphires. Amber is produced north of the jade mining area.

Due to various problems the Burmese mining industry encountered a decline in post-war production. Some of the causes for this downward trend were: lack of investment capital, a poor security situation in some mining areas, illegal mining and smuggling, and the depletion of high-grade reserves, coupled with insufficient exploration. The security situation is improving and loans are being raised to allow further exploration and mine development to be undertaken. There is certainly significant mineral potential in the country, but much of it remains to be realized.

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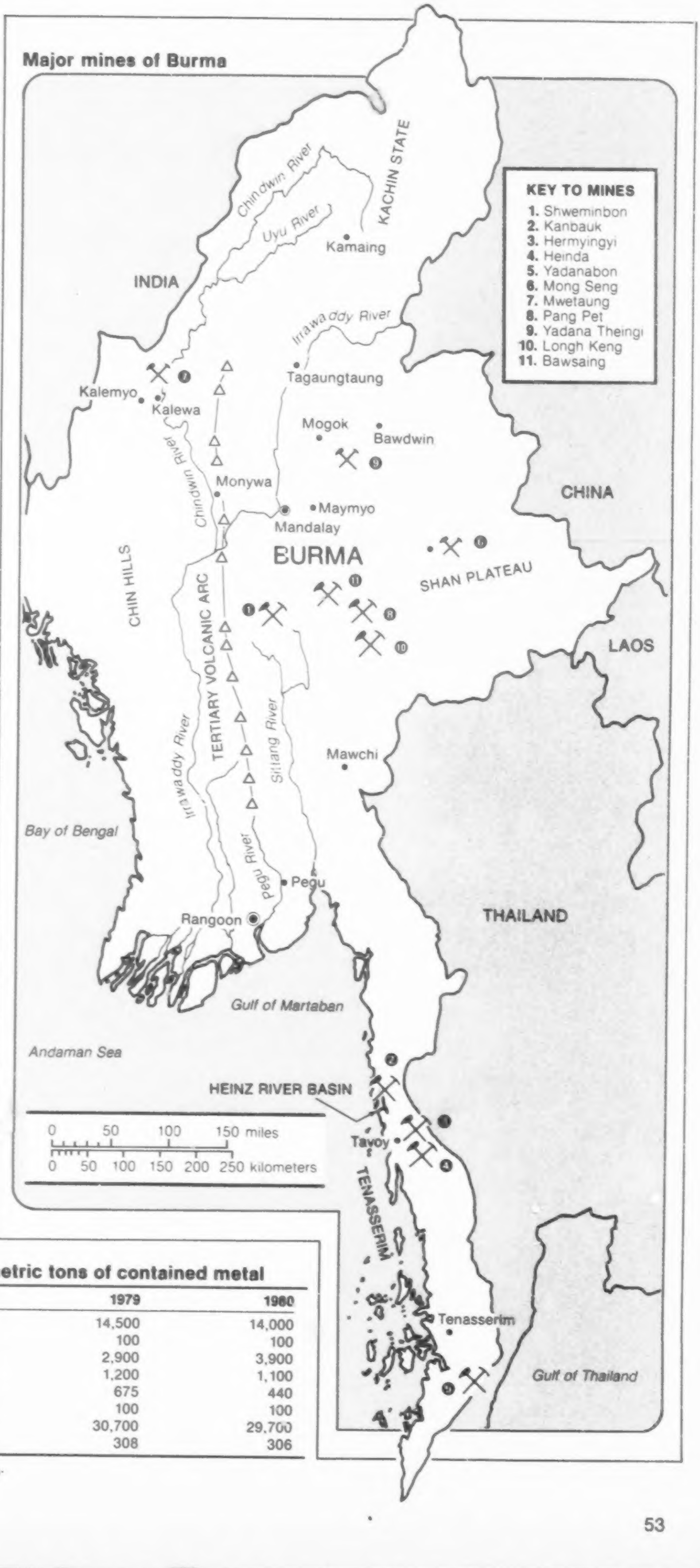
Major mines of Burma


KEY TO MINES
1. Shweminbon
2. Kanbauk
3. Hermyingyi
4. Heinda
5. Yadanabon
6. Mong Seng
7. Mwetaung
8. Pang Pet
9. Yadana Theingi
10. Longh Keng
11. Bawsaing
INDIA
CHINA
LAOS
THAILAND
BURMA
KACHIN STATE
Chindwin River
Uyu River
Kamaing
Irrawaddy River
Tagaungtaung
Kalemyo
Kalewa
Mogok
Bawdwin
Monywa
Maymyo
Mandalay
CHIN HILLS
TERTIARY VOLCANIC ARC
SHAN PLATEAU
Sittang River
Mawchi
Bay of Bengal
Pegu River
Pegu
Rangoon
Gulf of Martaban
Andaman Sea
HEINZ RIVER BASIN
Tavoy
TENASSERIM
Tenasserim
Gulf of Thailand
0 50 100 150 miles
0 50 100 150 200 250 kilometers

Mine production in Burma expressed in metric tons of contained metal

Product	1978	1979	1980
Lead	9,200	14,500	14,000
Copper	100	100	100
Zinc	2,500	2,900	3,900
Tin	800	1,200	1,100
Antimony	600	675	440
Nickel	100	100	100
Silver[1]	25,000	30,700	29,700
Tungsten[2]	304	308	306

1. Kilograms. 2. Concentrate containing 60 percent WO_3.

Controlling Diesel emissions underground 48
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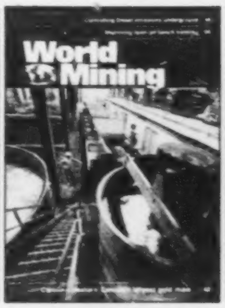
World Mining

JUNE 1982

Carolin—western Canada's largest gold mine 42



World Mining

JUNE 1982
VOLUME 35, NO. 6

THE COVER

After 10 years and $30,000,000, the Carolin gold mine in British Columbia, Canada went on-stream early this year. There are already plans to increase throughput from 1,500 to 2,400 tons per day. Like most of Canada's large gold operations, the metallurgical flowsheet is conventional, employing the Merrill-Crowe process. However, all crushing is done underground, and conventional is also not the proper word to describe operating results to date. *Photograph by Carolin Mines Ltd.*

Features

Carolin gold mine starts up 42

Western Canada's largest gold mine has exceeded designed production in a matter of weeks. Plans are to increase production to 300 ounces of gold per day. Kelson Collins, Rod Samuels, and John Bogert, all of Carolin Mines Ltd., provide all the details about this new operation

Diesel emissions underground 48

In Sweden, Diesel exhaust in underground mines, especially from Diesel LHD's, is of serious concern. The University of Luleå has exhaustively studied this problem, and has come up with recommendations that every underground miner should consider. Ove Rehnberg, Per-Arne Lindqvist, Anders Sundgren, Michael Norlund, and Bengt Schmidtbauer have the report

Mining in India 57

The Indian mining industry has been growing since independence, and today produces 64 commodities, worth well over $2,500,000,000 annually. N. V. Eswar outlines the past, and tells of future prospects for his country in the world of mining

Open pit bench blasting 64

Lothar Buchta is a recognized expert in the field of blasting. In this article, he combines theories and practical field experience in explaining how open pit bench blasting can be improved

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The use of Diesel engines underground poses many questions about emissions and their effects. This is especially true in Sweden, where Diesel power, particularly on LHD's, is very common. Research has focused on constructing a model based on typical LHD use

Controlling Diesel emissions underground

Diesel-powered equipment is used frequently in underground mining in Sweden, and there is consequently a deep concern among the miners about the health effects of Diesel exhaust.

Great efforts have been undertaken to reduce the emission of Diesel exhaust. Low emission engines, low sulphur fuels (that is, those that have a sulphur content of less than 0.1 percent), and exhaust cleaners are used. Furthermore, the mines are ventilated with large quantities of fresh air. The increasing energy prices during the last years, coupled with the fact that the fresh intake air must be preheated during seven to eight months of the year in Sweden, do not favor increased ventilation capacities. On the contrary, there is a demand for a better distribution of the air that is presently being used in the mines.

The best way to eliminate the Diesel emissions is, of course, to use as "clean" engines as possible. Swedish regulations do not include certification of Diesel engines. The exhaust emissions have to be checked every 150 working hours. If 50 percent of the smoke and 25 percent of stipulated carbon monoxide values are exceeded (the stipulation values are 20 percent Hartridge for smoke and 800 parts per million for Co at full engine load), the equipment has to be taken out of operation.

The choice of low emission engines for underground operation is not easy, however, and there has been a great need for common specifications that would be accepted by the mining engineers as well as engine manufacturers.

In this article we describe a simulated duty load cycle for Diesel-powered machines in underground operation, as a partial result of our ongoing research in the area of Diesel exhaust purification. The aim of this specific project has been to establish a test cycle that can serve a a model for both mining engineers and engine manufacturers in their future selection, testing, and development of Diesel-powered machines.

Independently of our research, mining industry of North America has also been dealing with the same tasks[1,3].

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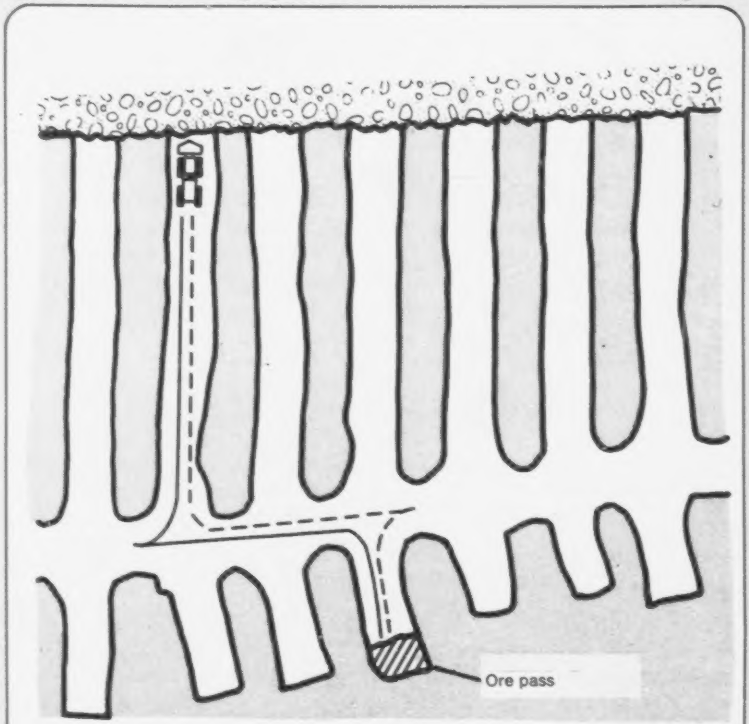
Typical sub-level caving operation **Figure 1**



Project Steps Followed

The development of one final duty cycle, based on different mining methods and a variety of operating conditions, was done by a step-by-step evaluation:

- The number and the types of Diesel-powered mining vehicles underground and their contamination of the air were ascertained by an enquiry to all mining companies in Sweden. The development of a duty cycle for the primary air contaminators, load-haul-dump machines (LHD's), was agreed upon.
- The use of LHD's with regard to the character of the operation and the working environment was described by evaluation of industrial engineering time studies and visits to operating mines. The character and the time of typical LHD working modes was then defined.
- LHD cycles were recorded with portable instrumentation to characterize the engine load during different LHD modes. The recordings were made on different types of LHD's in different mines.
- A representative recorded LHD cycle was simulated in an engine laboratory to permit exhaust emission measurements during dynamic LHD work. The exhaust emissions were analyzed during both this LHD cycle and static loads to evaluate the importance of transient loads.
- Based on the field registrations and the exhaust emission measurements, a duty cycle for LHD's was defined.

Diesel-Powered Mine Equipment

The enquiry to the Swedish mining industry included questions concerning planned mine production, mining methods, number and types of Diesel-powered equipment, Diesel engines, and transmission types of working cycles, etc.

The result of the enquiry, representing the situation in 1977 in 37 mines with a total planned production of 53,000,000 tons per year, is shown in Table 1. As expected, the LHD's are the main fuel consumers (50 percent) and, consequently, the main contaminators of the air. Furthermore, the LHD's operate in spaces that are most difficult to ventilate effectively. Therefore, the subsequent work was concentrated on a duty cycle for this type of equipment.

LHD Working Cycles

Data from industrial engineering time studies and visits to mines were carefully evaluated, in order to obtain detailed information about typical working cycles and operating conditions that are encountered.

Many different LHD load cycles were observed. One typical application is operation on sub-level caving with fairly straight roads, as shown in Figure 1. Another example is in cut-and-fill mining where the roads are narrow and soft, and partly up and partly down. Average hauling distance for the transport of rock to the ore passes is 330 to 400 feet (100 to 120 meters) in a single route. Due to the fact that many small single mines have a shorter tramming distance, and because 30 percent of the total quantity of rock is loaded onto trucks, a hauling distance of 265 feet (80 meters) was chosen.

Mainly due to the extensive use of sub-level caving in Sweden (65 percent of the handled ore) a working with fairly "high speed" modes was selected for further development. This cycle, described in Table 2 is also typical for sublevel stoping and block caving, except for the badly fragmented rock that is often obtained by block caving.

Field recordings

The load cycle recordings included measurements of engine speed, fuel consumption (via fuel rack position), exhaust temperature and turbocharge pressure (on turbocharged engines) to describe the engine work. In addition, the vehicle speed was measured, to facilitate timing within the recorded cycles. A typical recording is shown in Figure 2.

Two types of LHD's are used in Swedish underground mines: loaders specially constructed for underground work (Wagner, Toro) and standard loaders modified for underground work (Volvo BM, Caterpillar). Since the number of loaders specially constructed for underground use is expected to increase more than the others, the main recordings were were done on a Wagner ST8 LHD in the Grängesbergs mine of Gränges AB. Complementary studies were carried out on two standard load-

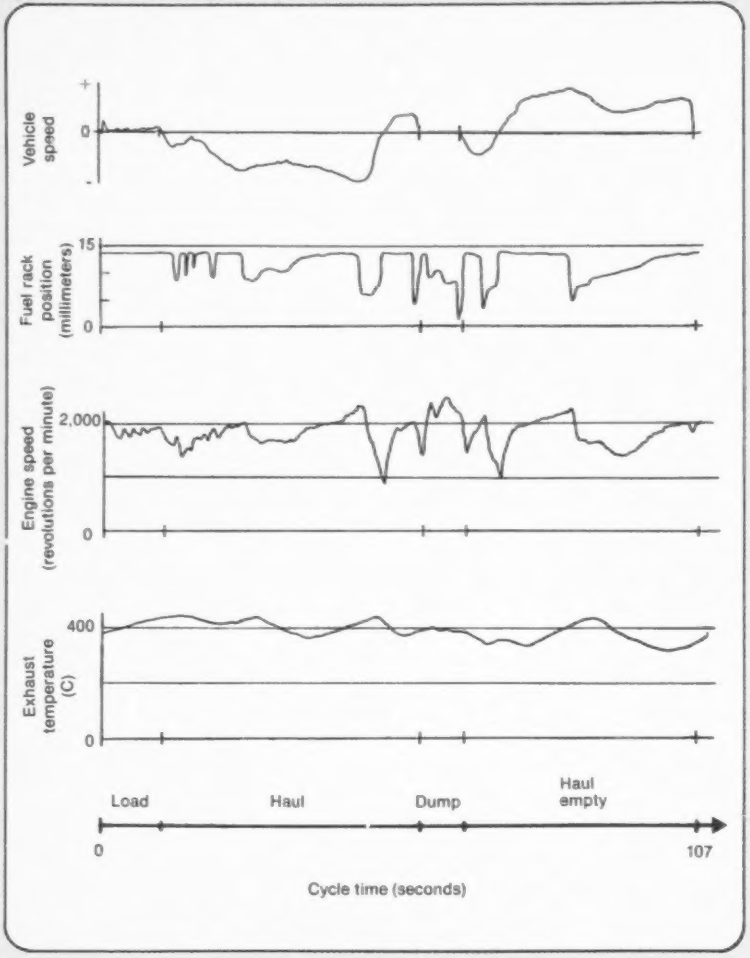
Table 1.
Types and number of Diesel-powered equipment and their fuel consumption in Swedish underground mines in the beginning of 1977.

Type of equipment	Number in operation	Total fuel consumption liters per day	Percent of total fuel consumption
Drilling jumbos	200	2,100	2
Charging (blast hole loading) vehicles	70	1,100	1
Working platform for scaling, roof bolting, etc.	220	5,000	5
LHD's	310	49,600	50
Ore haulage trucks	230	31,600	32
Locomotives	90	2,000	2
Service and material transport vehicles	320	4,600	4
Personnel transport cars	260	3,600	4
Totals	1,700	99,600	100

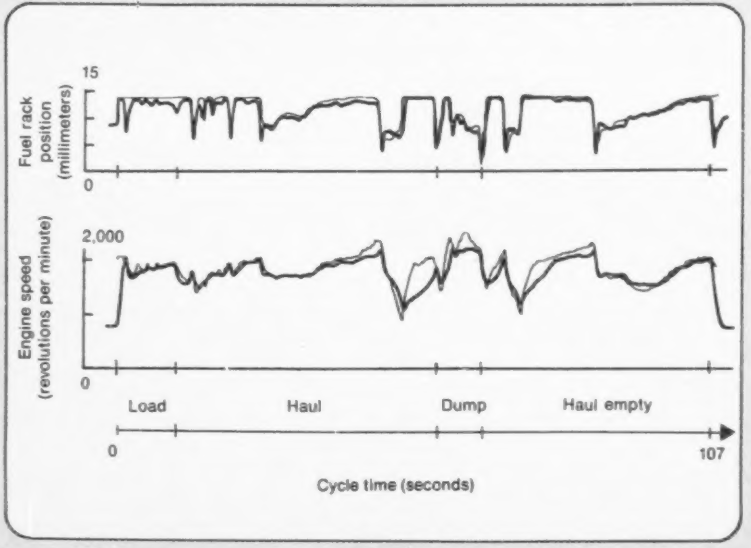
Table 2.
Description of segments in the selected load-haul-dump duty cycle

Cycle segments	Description of cycle segment	Time per segment (seconds)	Percent of quantity rock loaded
Load	Fairly well fragmentated rock. Five to 10 boulders per 1,000 ton of rock loaded	30	65
Haul loaded	Horizontal road in good condition with few curves. Average tramming speed 4.7 miles per hour (7.5 kilometers). Hauling distance 265 feet (80 meters)single route. One turn included.	38	65
Dump	Dump in shaft on road level with a wheel barrier and good space for the bucket during dumping.	6	70
Haul empty	Same as for haul loaded. Average tramming speed of 5.3 miles per hour (8.5 kilometers)	34	65
Idle		9	Not calculated
Unspecified, low engine power	Unspecified work such as tramming to working place, cleaning of loading and dumping spots, road maintainance, etc., mainly with low engine power	9	Not calculated
Unspecified, high engine power	Unspecified work such as dozing and final loading at beginning and end of each round, scaling with the bucket, etc., mainly with high engine load		Not calculated
Total		138	

Typical load cycle recording **Figure 2**



Agreement between field and lab test **Figure 3**



ers, a Volvo BM 1641 in the Långsels mine of Boliden Mineral AB, and a Caterpillar 980B in the Kiruna mine of Luossavaara-Kirunavaara AB.

The recorded working cycles were evaluated with a mini-computer. The combinations of engine speed and fuel rack position values sampled 10 times per second were presented in matrices to give typical speed load levels for each LHD operation. Each duty cycle was compared to the sum of all cycles to find a representative cycle.

LHD Load Cycle Simulation

The objective was to transform the load variations recorded in the field as closely as possible into the laboratory environment, thus permitting representative dynamic measurements of engine emissions and other variables of interest.

The laboratory tests were carried out on a Diesel engine of the same type that powered the Wagner ST8 LHD, a Deutz F10L 714 IDI air-cooled Diesel. In order to reduce any difference between the two engines, they were equipped with the same fuel injection pump. The engine was coupled to a hydraulic dynamometer equipped with electrical control and force measuring units. Throttle actuation was done with a specially designed high band width stepping motor servo system. The control of the engine dynamometer was performed with a minicomputer. This technique has been described elsewhere. The agreement between a load cycle recorded in the field (thin curves) and the same cycle reproduced in the laboratory (thick curves) is shown in Figure 3. As can be seen, correspondence is good over most parts of the trajectory.

Exhuast Emissions

The exhaust emission tests were carried out both under the dynamic LHD load cycle and under steady state loads. Each test included the measurement of exhaust emissions (NO_x, HC, CO, and CO_2) as well as other parameters (engine speed, engine load, exhaust, air temperatures, air and fuel consumption) that are necessary for the calculation of the mass emissions (grams per hour and grams per kilowatt hour). The sample system was designed to give high flow rates and small dead volumes. Corrections for the signal delay from the instruments and calculations of the mass emissions were performed continuously with the minicomputer. A light low sulphur (S equal to 0.05 percent) fuel was used under all tests.

Figure 4 shows the emissions under

steady state loads (points) and under the dynamic LHD cycle (recorder traces). The points represent concentrations that have been measured under static tests at the same speed/load combinations as in the dynamic cycle. The good agreement between the points and the curves does not speak for higher emissions under transient conditions. Neither do the acceleration modes show any extraordinarily high emission peaks.

Complementary measurements were carried out on a turbocharged engine (Scania DS8) and the results did not alter the conclusions listed above.

Simplified LHD Load Cycles

When it became obvious that steady state tests can be used in place of dynamic tests the development of a steady state LHD load cycle started.

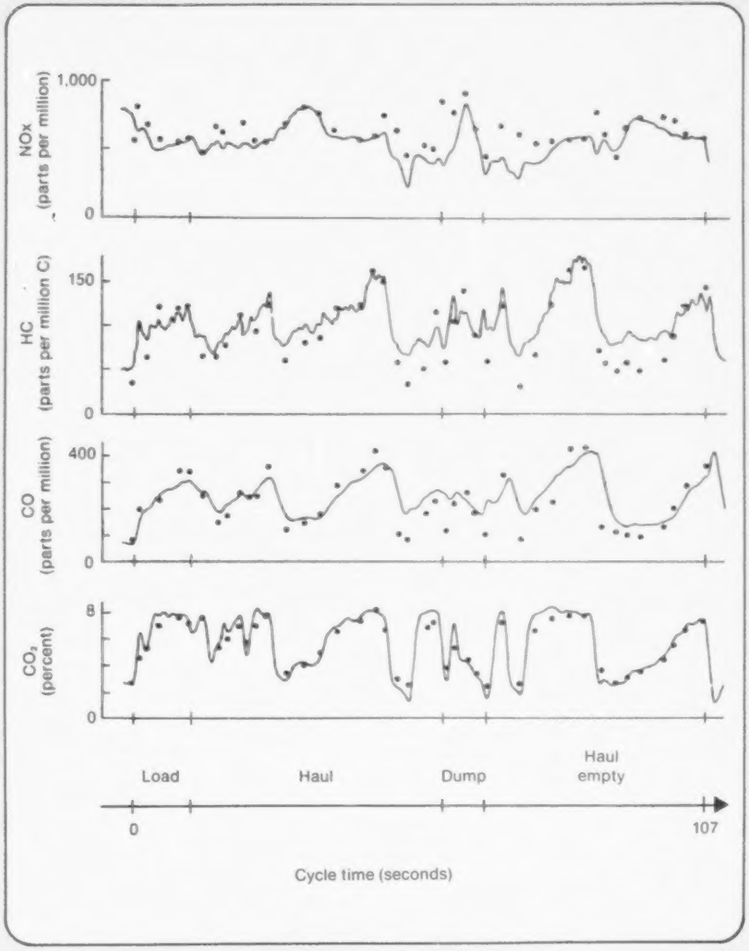
An analysis of all field registrations showed that, when broken down, LHD operation can be described by a total of 15 characteristic modes. See comparisons in Figure 5.

It was recommended to the Swedish Mining Association to take the responsibility of how to use the load cycles

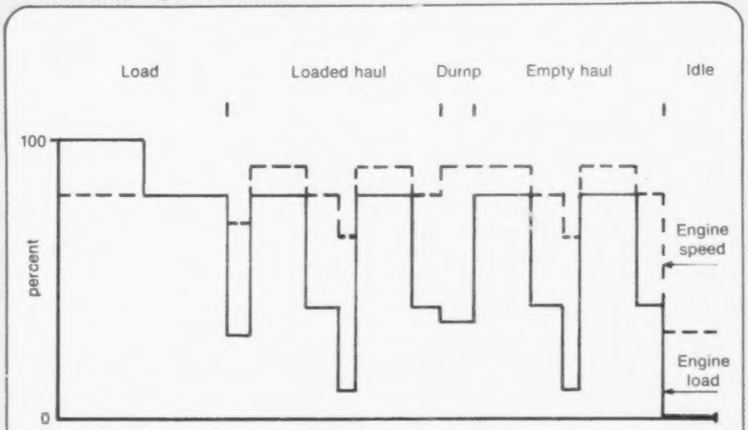
Mode 1: Load-acceleration into muckpile, start filling bucket.
Mode 2: Load-bucket is filled under back and forth movement.
Mode 3: Haul loaded-bucket is rocked back and lowered, tramming mode is prepared
Mode 4: Haul loaded-acceleration back
Mode 5: Haul loaded-cruising to turning point
Mode 6: Haul loaded-turning
Mode 7: Haul loaded-acceleration forward
Mode 8: Haul loaded-cruising to ore pass
Mode 9: Dump
Modes 10-14: Haul empty (compare with modes 4 to 9)
Mode 15: Idle

The engine speed-load levels of each of these modes are based on data that originally come from the speed-load ma-

Emissions levels **Figure 4**



15-mode LHD cycle **Figure 5**



trices and the recorder traces.

"Unspecified work", described in Table 2, was found to be much the same as the work in the modes 1 to 14. Consequently, the time of "unspecified work" was divided proportionally into modes 1 to 14.

As the speed load levels in some of the modes are identical, the 15 modes can be reduced to a total of eight modes. The result of this reduction is a simplified LHD duty cycle of eight steady state steps, as illustrated in see Figure 6. The weighting factors, which are equal to the relative time of each mode, are necessary for the calculation of the mass emission over the cycle.

The eight-mode cycle should mainly be employed for the selection of low emission engines, while on the other hand, the 15-mode cycle (run dynamically) should be used whenever a dynamic parameter is important for the result (for example, using the exhaust temperature paramter when developing Diesel exhaust cleaners).

LHD operation can be described by 15 characteristic modes; a simplified outline would have eight modes

Developed LHD Duty Cycles

In the final report we recommended to the Mine Safety Committee of the Swedish Mining Association that that organization should take the responsibility of how to use the developed load cycles in the future.

To get a fast and definite decision on how to use the proposed duty cycles, the Mine Safety Committee invited all people who would be dealing with this matter to attend a two-day work shop, which was held at the University of Luleå, where all present could voice their opinions about it. Participants in this work shop included representatives from all areas, including engine, machine, and fuel manufacturers; mines; government; and labor unions.

Based on decisions during the workshop, the Mine Safety Committee will send a recommendation to all Swedish mines, which can be summarized as follows:

- For all Diesel-powered mining machines without any exhaust cleaning devices, the mines shall demand exhaust emission specifications according to the eight-mode LHD cycle and Cal-13 cycle.

- For machines that are equipped with exhaust cleaning devices, the emissions shall be determined by using the eight-mode cycle

- All emission tests must be carried out with a carefully specified light Diesel fuel, as shown in Table 3

- The specific exhaust emissions (measured in grams per kilowatt hour), according to the eight-mode LHD cycle, should be lower than those that are demanded by the state of California, United States according to the California 13 mode cycle.

Table 3.
Specifications for light Diesel fuel

Cetane number	Minimum 45
Viscosity at 20° C[1]	Minimum 1.6
Cold filter plugging point	Maximum minus-40°C
Flash point	Minimum 40°C
Distillation	
10 percent evaporated	Maximum 200°C
50 percent evaporated	170-220°C
90 percent evaporated	Minimum 210°C
EBP evaporated	Minimum 210 Maximum 300°C
Density at 15°C	0.78-0.81
Water and sediment content (percent by volume)	Maximum 0.01
Sulphur content (percent by weight)	Maximum 0.06
Smoke point (millimeters)	Minimum 30

1. Square millimeters per second.

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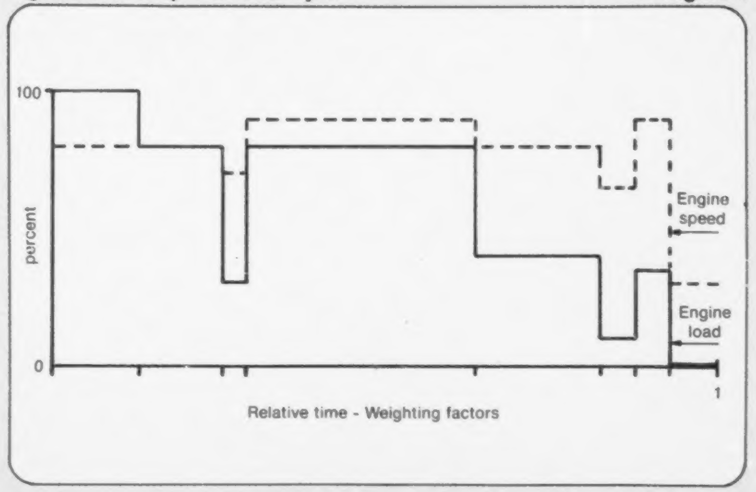
The authors wish to thank all Swedish mining companies for the help in answering the enquiry about Diesel equipment, and wish to particularly thank the Grängesberg, Längsele, and Kiruna mines for cooperation during the field recordings. The loan of engine details from Svenska Deutz AAB, Volvo BM, and Engström and Nilsson AB is greatly appreciated.

The project advisory group consisted of professor Lars Collin (Chalmers University of Technology), chief engineer K-G Andersson (AB Volvo Penta), manager Curt Hallberg (Swedish Steel AB) and chief designer Kurt V. Olsson (Saab-Scania). The project advisory group is gratefully acknowledged for valuable advice and criticism. The project was financially supported by the Swedish Work Environmental Fund. ■

Eight-mode simplified LHD cycle **Figure 6**



With a wide range of mineral products and prospects,
and great potential for mineral industry expansion,
India is a fast growing mining and mineral exporting country.
Much capital investment is planned for the next few years

The Indian Mining Industry

By **N. V. Eswar**
Madras, India

At the time of independence in 1948, India was producing just 24 minerals on an industrial scale. Over the last three decades the country has added 40 minerals to that list. Today, the value of all 64 minerals produced annually is estimated to be some $2,683,000,000. In 1977, this value was only $1,959,000,000.

During the period of British colonial rule there was little development outside the Bengal-Bihar belt. Development outside this area since independence is one of the main reasons for the increased stature of the country's mining industry. The State of Bihar now accounts for 29.5 percent of the minerals produced, Madhya Pradesh 16.5 percent, West Bengal 10.7 percent, and the remainder is shared by the states of Rajasthan, Andhra Pradesh, Gujarat, Maharashtra, Karnataka, Tamil Nadu, etc.

The central government is spending a total of $1,725,000,000 on the development and expansion of the non-ferrous sector during the Sixth Plan period, ending in 1985. Over the same period, about $140,000,000 is allocated for mineral development by the various state governments. In 1980, India exported mineral products valud at $551,794,125. Although the country has been well-mapped geologically, there has not been a great deal of exploration on a large, modern scale. There remains a great deal of unrealized potential.

Bauxite and aluminum

India's reserves of bauxite are more than 18,000,000,000 metric tons containing between 43 and 49 percent Al_2O_3. The thickness of the deposits ranges from 2 to 54 meters (6.6 to 177 feet). Bauxite occurs in the following states: Bihar, Goa, Madhya Pradesh, Maharashtra, Tamil Nadu, Gujarat, Karnataka, Orissa, Andhra Pradesh, and Uttar Pradesh.

The Geological Survey of India recently reported very large deposits along the eastern coast of Andhra Pradesh and Orissa. These cover an area of 25,000 square kilometers (9,650 square miles), stretching for 300 kilometers (186 miles), with a width of 40 to 100 kilometers (25 to 62 miles). Individual bauxite deposits are reported to contain between 2,000,000 and 300,000,000 tons. This new bauxite discovery has added some 2,269,000,000 tons to the known reserves. As a result of this discovery, the government is likely to build an alumina complex at Kondapalle, with assistance

STRIPPING OVERBURDEN at an open pit coal mine near Dhanbad, Bihar. The L & T Poclain hydraulic excavators are manufactured locally, under license, by Larsen & Tonbro.

from the Soviet Union. Ultimately, production should reach 800,000 tons of alumina per year (see WORLD MINING, April 1982, page 83).

In all, 68 mines are in operation, but only nine of them produce more than 50,000 tons per year, accounting for 76 percent of production. In 1977, production was 1,425,634 tons, going up to 1,951,933 tons in 1979, but falling again in 1980 to 1,645,218 tons, mainly due to power shortages. In 1981, production was up again, to 1,912,000 tons. Almost all the mines are open pits, generally well mechanized.

Diaspore ($Al_2O_3.H_2O$) in bauxite occurs in the Chhatarpur, Shivpuri, and Tikamgarh districts of Madhya Pradesh and Jhansi and Lalitput districts of Uttar Pradesh. Madhya Pradesh accounts for over 70 percent of production, which was 7,030 tons in 1977. Output subsequently fell to 5,680 tons in 1980.

During 1980-1981, production of aluminum was 200,000 tons, but capacity utilization was only 62 percent. It rose again to 212,844 tons in 1981. Total installed capacity is put at 321,170 tons: 100,000 tons from the public sector through Bharat Aluminium Company at Korba in Madhya Pradesh, and 221,170 tons from the private sector, including The Indian Aluminium Company, with smelters at Hirakud (20,320 tons) in Orissa; Alwaye (15,850 tons) in Kerala and Belgaum (60,000 tons) in Karnataka; Hindustan Aluminium Corporation at Renukoot (100,000 tons) in Uttar Pradesh; and Madras Aluminium Company at Mettur (25,000 tons) in Tamil Nadu.

Additional capacity of 4,150 tons is to be installed at the Hirakud plant and 20,000 tons at the Renukoot plant, raising the installed capacity to 345,320 tons. Domestic demand is currently running at a level of between 325,000 to 350,000 tons. Therefore it has been necessary to import some aluminum to meet the demand in full. Some 130,000 tons were imported in 1980-1981.

Current estimates put the demand for aluminum at 445,000 tons by 1985, rising to 650,000 tons by 1989. The country's aluminum industry should be able to meet this increase with current projects that are underway. An aluminum smelter is under construction at Damanjodi in Orissa, with assistance from Aluminum Pechiney (see WORLD MINING, December 1980, page 74). The smelter will have a capacity of 218,000 tons per annum. There is also the new alumina plant to be built at Kondapalle, as mentioned above. In addition, almost $84,000,000 is to be spent on the modernization of the Korba plant. Various studies are also underway, including the use of froth flotation for the beneficiation of low-grade bauxite.

Copper

The major producing states are Bihar and Rajasthan, in that order. The main production centers are: Mosaboni, Pathargora, Surda, Kendadih, and Rakha areas in the Singhbhum district of Bihar; Khetri and Chandmari areas in Jhunjhunu district; and Dariba in the Alwar district of Rajasthan.

Five years ago, the largest known copper deposit in India was discovered in the Malanjkhand area in Madhya Pradesh. The reserves are believed to be 65,000,000 tons of ore containing 1.3 percent Cu. Total reserves for the country are 400,000,000 tons of ore containing 5,020,000 tons of metal. Other recent discoveries include: smaller deposits in the Wari area of Chitorgarh district; Rajasthan, in the Chandrapur district of Maharashtra; and in the Kesarpur area of Mayurbhanj district, Orissa.

The Indian Copper Complex, of Hindustan Copper Ltd. at Ghatsila in Bihar, has a smelter with an annual capacity of 16,500 tons, along with supporting mines. Capacity of the Mosaboni mine is to be increased from 50,000 tons to 80,000 tons of ore per year at an estimated cost of $7,500,000. At the same time, the capacity of the Ghatsila smelter is to be raised to 20,000 tons per year. The refining capacity is also to be raised to 20,000 tons from the current level of 8,400 tons. A precious metals refinery has been put into operation at Ghatsila which, in 1980-1981, produced 400 kilograms (12,860 ounces) of silver, 40 kilograms (1,286 ounces) of gold, 2.5 tons of selenium, and 170 kilograms of nickel sulphate.

Other facilities at Ghatsila include a full-scale pilot plant to recover tellurium from anode slimes. Some 100 kilograms (3,215 ounces) with a purity of 98 percent are recovered annually. A plant has also been set up to recover cobalt through hydrometallurgy. Pilot plant work is being carried out to improve copper refining by the use of high current density and periodic current reversal. A cement-copper precipitator has been installed for the recovery of copper by leaching low-grade oxidized and lean sulphide ores. The Copper Complex also produces kyanite from its Laspsoburu mines. Output in 1979-80 was 17,557 tons.

The country's first large, hard rock, open pit mine, the Malanjkhand Copper Project in Madhya Pradesh, has been designed for an output of 2,000,000 tons of ore per year, for the production of 23,000 tons of metal. The concentrate produced will be smelted at Khetri. The Khetri Copper Project has a capacity of 31,000 tons of copper per year, but this is to be expanded to 45,000 tons.

There are 13 mines in operation and ore production amounted to 2,042,016 tons in 1980. Metal production in 1980 comprised 27,940 tons of blister copper, 18,802 tons of cathode copper, and 14,189 tons of wire bars. Electrolytic copper production in 1981 was just 14,764 tons. Current demand is about 90,000 tons and is expected to reach 117,000 tons by 1985. Nearly 50,000 tons of copper in various alloys and forms are imported annually to meet domestic needs.

Lead and Zinc

The country's total ore reserve is 212,000,000 tons, with a metal content of 12,000,000 tons. Most of the ore, 176,493,000 tons, is in the Ajmer, Bhilwara, Sirohi, and Udaipur districts of Rajasthan. The majority of the remainder is found in the following districts: Cudappah, Guntur, and Ongole districts of Andhra Pradesh (14,398,000 tons); the Banaskantha and Baroda districts of

Gujarat (9,550,000 tons); the Sundergarh district of Orissa (6,010,000 tons); the Darjeeling district of West Bengal; and the South Arcot district of Tamil Nadu. Smaller quantities of less than 1,000,000 tons are situated in Sikkim, the Pithoragarh district of Uttar Pradesh, the United Khasi, and the Jaintia Hills area of Meghalaya.

Recent exploration has shown estimated reserves of 1,520,000 tons of ore in the Malikhera area of West Bengal, and mineralization has also been established in the Dalingcho block in West Bengal. The Geological Survey of India (GSI) also considers the Piperia area of Rajasthan a promising prospect for substantial lead-zinc reserves. GSI exploration for copper-lead-zinc ore is continuing at Askot in Uttar Pradesh, Dikchu in Sikkim, and Kesarpur in Orissa.

An important development has been the discovery of the largest single deposit in India, the Rampur-Agucha deposit. Estimated reserves are 35,000,000 tons at a combined grade of 10 percent. The deposit is suitable for open pit mining.

The important mines are: the Zawar group of mines; the Rajpura-Dariba mines in Rajasthan; the Sargipalli lead mine in Orissa, and the Agnigundala lead mine in Andhra Pradesh. These are all operated by Hindustan Zinc Ltd., which also operates the zinc smelter at Debari in Rajasthan, the lead smelter at Tundoo in Bihar, and the lead-zinc smelter at Vishakhapatnam in Andhra Pradesh. Other producers include: Hindustan Zinc, as a byproduct; Sikkim Mining Corporation, also as a byproduct from copper production; and Cominco Binani Zinc Ltd., in Kerala.

Developments include the expansion of production from 120 to 240 tons of ore per day at Agnigundala lead mine and a 500-ton-per-day beneficiation plant to be set up at Sargipalli lead mine. A leach residue plant is being built at the Debari zinc smelter, employing the Outokumpu process. Silver will also be recovered using a process developed by Mitsubishi. The Vishakhapatnam smelter is having its capacity raised from 10,000 to 22,000 tons per year. Pilot plants have been set up at Debari and Vishakhapatnam to enrich the Pb and Ag values contained in anode slimes to enable their recovery through a combined hydrometallurgical-pyrometallurgical process. In addition to modernization of the Tundoo lead smelter, a pilot plant has been set up at Ambaji in Gujarat to produce a copper-lead-zinc bulk concentrate.

Production in 1981 was 20,017 tons of lead concentrate and 52,876 tons of zinc concentrate, compared with the 1980 figures of 16,827 and 71,777 tons, respectively. Metal production in 1981 was 14,325 tons of lead and 57,434 tons of zinc.

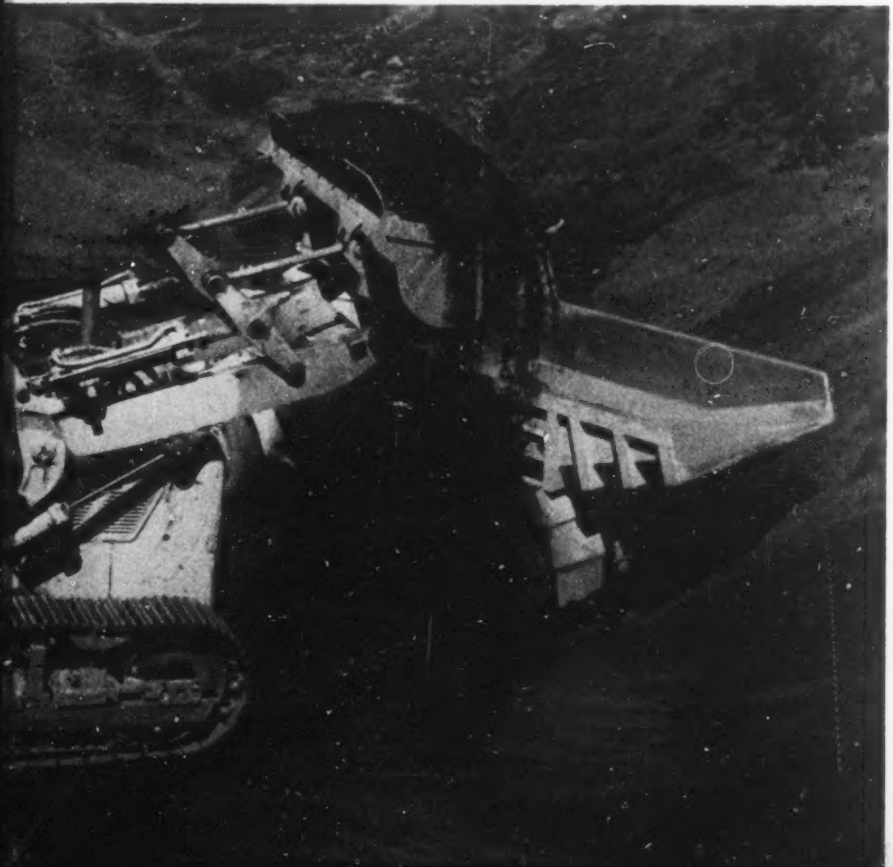
The zinc smelters at Debari and at Binanipuram (Cominco Binani) are the main producers of cadmium, as a byproduct. The Debari smelter can produce 190 tons a year while the Binanipuram smelter produces 36 tons a year. The new Vishakhapatnam smelter will have a capacity of 115 tons of cadmium per year. This increased production will more than meet domestic demand.

Most silver production also comes as a byproduct from the lead-zinc industry, from the lead smelters at Tundoo and Agnigundala and the Vishakhapatnam zinc smelter. It is also produced as a byproduct by the Kolar and Hutti gold mines and a small quantity is recovered in the copper refineries of Hindustan Copper in Rajasthan and Bihar. Bharat Gold Mines also recover some 615 kilograms (19,772 ounces) from film wastes each year. Output increased dramatically in 1981 to 17,263 kilograms (555,005 ounces) compared with 11,721 kilograms (376,830 ounces) in 1980.

Iron Ore

Most of the country's vast reserves of iron ore occur as hematite, amounting to 10,500,000,000 tons. Reserves of magnetite reach 3,000,000,000 tons. The Singhbhum district alone has reserves of 3,060,000,000 tons of hematite, while the Cuttack, Dhenkanal, Keonjhar, Koraput, Mayurbhanj, Sambalpur, and Sundergarh districts of Orissa account for 2,700,000,000 tons. The Bastar, Drug, Gwalior, Jabalpur, Khargone, and Sidhi districts of Madhya Pradesh contain an additional 2,260,000,000 tons; the Bellary, Bijapur, Chickmagalur, Chitradura, North Kanara, Shimoga, and Tunmkur districts of Karnataka contain 1,070,000,000 tons; Goa contains 356,000,000 tons, and the Chandrapura and Ratnagiri districts of Maharashtra have 237,000,000 tons. There are smaller deposits in Rajasthan and Andhra Pradesh.

Chickmagalur and Shimoga also have reserves of 2,120,000,000 tons of magnetite, while the districts of Coimbatore, Nilgiris, Dharmapuri, Salem, North Arcot, South Arcot and Tiruchirapally of Tamil Nadu state contain a further 500,000,000 tons. Elsewhere, there are 240,000,000 tons in the Adilabad, Khamman, Nizamabad, Ongole, and Warrangal districts of Andhra Pradesh; 80,000,000 tons in the Kozhikode



CLEAN-UP OPERATIONS are in progress at one of the iron ore mines located in the state of Goa. Iron ore reserves in Goa amount to an estimated 356,000,000 tons.

and Malapparam districts of Kerala state; 47,000,000 tons in the Goalpara area in Assam; and smaller deposits in Nagaland, Haryana, and Bihar.

Production of iron ore from 386 mines, which are both mechanized and semi-mechanized, and 10 processing plants amounted to 39,000,000 tons in 1980. The demands of the country's seven integrated steel mills and six sinter plants accounted for 14,800,000 tons and the remainder of the ore was exported. In 1981 iron ore output rose to 41,122,000 tons. Iron and steel industry products that year were: 10,269,000 tons of steel ingots; 31,066 tons of ferrochrome, 208,836 tons of ferromanganese; 159 tons of ferromolybdenum; 60,253 tons of ferrosilicon; 170 tons of ferrotitanium; 11 tons of ferrotungsten; as well as 113 tons of ferrovanadium.

A recent major development was the completion of the Kudremukh project in Karnataka state (see WORLD MINING, May 1982, page 74), with facilities to pump slurry over a distance of 67 kilometers (41.6 miles) to the port of Mangalore on the west coast. This project was initially established with $630,000,000 in financial aid from Iran. It will supply a total of 150,000,000 tons of concentrate to Iran at the rate of 7,500,000 tons a year for the next 20 years. The plant was specially designed to upgrade low-grade magnetite-hematite ores, averaging 39 percent Fe, to a concentrate containing an average 66.5 percent Fe. Because of doubts about Iran's ability to fulfill its contractual obligations for concentrate deliveries, the government has approved plans to set up pellet plants at Mangalore and Bailadila. The pellets will be bought by Indonesia.

Exploration for magnetite deposits continues in: Kumaraswamy, Babubudan Hills, and the west coast of Karnataka; in Ongole in Andhra Pradesh; and at Malangtoli in Orissa. In addition, a number of mine expansions are underway or planned.

The Meghataburu iron ore project has been developed with a production capacity of 1,340,000 tons of lump ore and 2,960,000 tons of fines each year. The capacity of the Kumaraswamy and Donimalai mines is to be raised from 95,530,000 to 127,000,000 tons. Deposit No.5 at Bailadila is to be developed to produce 240,000,000 tons including 41,000,000 tons of ultra-fines.

The GSI has also established additional reserves of 134,000,000 tons of ore at Deposit No.11C at Bailadila, some 540,000,000 tons of ore at Bastar in Madhya Pradesh, and 45,000,000 tons of magnetite ore in the Theerthamala area of Dharmapuri district, Tamil Nadu.

Manganese and Chromite Ore

Total reserves are 79,500,000 tons, of which 11,870,000 tons are proven, 17,880,000 tons are indicated, and 49,730,000 tons are inferred. The Bolangir, Keonjhar, Sambalpur, and Sundergarh districts of Orissa contain the largest reserves of 31,000,000 tons. In Balaghat district of Madhya Pradesh, there are 12,000,000 tons; in Bhandara and Nagpur districts of Maharashtra, 9,000,000 tons; in Bellary, Chitradurga, Nikana, Shimoga, and Tumkur districts of Karnataka, 7,000,000 tons; with smaller reserves in Goa, Gujarat, Andhra Pradesh, and Rajasthan. Additional, small reserves have recently been established in the states of Madhya Pradesh and Maharashtra.

A total of 316, mainly open pit, mines are operating in the country. Five of the mines in Maharashtra and three mines in Madhya Pradesh are underground. Only 30 mines are mechanized, most of the others are semi-mechanized. The Dongri-Buzurg mine in Maharashtra is the largest producer of high-grade manganese ore.

Orissa produces well over one-third of the ore mined. Ore production during 1980 reached 1,740,000 tons. The bulk is consumed locally, although 424,000 tons were exported in 1979. The government-owned Electrosmelt unit at Chandrapur in the state of Maharashtra manufactures some 50,000 kilograms (110,254 pounds) of ferromanganese each year. There are seven other units, all of which together have a capacity of 232,400 kilograms (512,460 pounds) of ferromanganese per year. Actual production in 1980 totalled only 159,250 kilograms (351,160 pounds).

Estimated proven reserves of chromite amount to 17,300,000 tons, of which nearly 80 percent is located in Orissa. Recent exploration completed by the GSI has indicated additional reserves of 31,170,000 tons of ore in the Bhimtanagar area of Orissa. It is believed that the Sukinda, Dhenkanal, and Keonjhar districts of Orissa also have substantial reserves.

There are additional indicated reserves in Orissa totalling 82,000,000 tons, of which 29,270,000 tons are metallurgical grade. Production of chromite amounted to 307,975 tons in 1980, the majority of which, 255,844 tons, was exported. Output in 1981 reached 334,681 tons.

Ilmenite and Rutile

The beach sands of Kerala, Tamil Nadu, Andhra Pradesh, Orissa, and Maharashtra are the main sources of supply, with additional reserves in the beach sands of Karnataka and Goa. The ilmenite of Chawwara beach in Kerala is particularly high in TiO_2.

Indian Rare Earths Ltd., owned by the government, and Kerala Minerals and Metals Ltd., owned by the Kerala state government, have set up processing plants at Manavalakurichi in Kanyakumari district and at Chawwara. The two plants at Manavalakurichi can process a total of 225,000 tons of ilmenite and 8,700 tons of rutile each year. The Chawwara plant can treat 50,000 tons of ilmenite and 5,000 tons of rutile per year. Its ilmenite capacity is to be increased to 200,000 tons.

Indian Rare Earths is setting up a new plant on the Chattarpur coast of Orissa, capable of treating 220,000 tons of ilmenite and 10,000 tons of rutile per year. Production of ilmenite is around 160,000 tons per year, while rutile output stands at about 7,500 tons.

Nickel and Vanadium

A very small quantity of nickel is produced as a byproduct by Hindustan Copper. The GSI reports nickeliferous laterite deposits in the following areas of Orissa: Kansa, Kumardah, Sarvabil, Sundergarh, Kalapani, Sukinda, and Simlipal. The total reserves are estimated to be only about 138,000,000 tons containing 0.97 to 1.09 percent nickel, at a cut-off grade of 0.52 to 0.9 percent Ni. Some 95 percent of these reserves are found in Sukinda.

To date there has been no development of this potential. However, there are plans to establish a plant to produce 4,800 tons of nickel and 200 tons of cobalt per year, based on the Sukinda deposits.

Visveswarraiah Steel Ltd., at Bhadravathy in Karnataka, has launched a pilot project to produce a small quantity of vanadium magnetite. Some vanadium is also produced from vanadium pentoxide waste of the aluminum industry.

Reserves of vanadium-bearing titaniferous magnetite are estimated to be 8,000,000 tons in Bihar and Orissa, 7,000,000 tons in Karnataka, and some 6,000,000 tons in Maharashtra. Indian bauxite also contains 0.01 to 0.2 percent vanadium pentoxide and the red mud slimes of alumina plants contain 4 to 15 percent V_2O_5. The GSI has estimated reserves of 4,000,000 tons of ore in the Masanikere area of Shimoga district, Karnataka, containing 1 percent V_2O_5. Five units manufacture ferrovanadium, production in 1980 being 128,095 kilograms (282,460 pounds).

Molybdenum and Tungsten

The Uranium Corporation of India at Jaduguda in Bihar produces molybdenum concentrate as a byproduct. This is the country's sole operating uranium mine to date. It is reported that the Dariba-Rajpura lead-zinc deposit contains recoverable quantities of molybdenum, in addition to bismuth, arsenic, and cadmium. The GSI has discovered indicated reserves of 36,000 tons of ore containing 0.14 percent Mo in the Karadikuthan area of Madurai district, Tamil Nadu. Elsewhere, it is continuing exploration of prospects in the North Arcot, Dharmapuri, Salem, and Coimbatore districts. Total production capacity is 1,200 tons of molybdenum per year. Actual production, however, has been only 150 to 200 tons, necessitating imports to meet domestic demand.

Tungsten vein deposits have only been found in Degana and Nagaur districts of Rajasthan and Bankura district of West Bengal. Deposits are reported in Andhra Pradesh, Karnataka, and Maharashtra, while some tungsten is recovered in the Kolar Goldfields. The Kolar plant can recover 40 tons of calcium tungstate per year from the treatment of 250 tons of tailings per day.

The reserves in Rajasthan state amount to 230,000 tons containing 0.27 percent WO_3, over a stoping width of more than 1 meter (3.3 feet). Total recoverable concentrate has been estimated at 1,230 tons. The Kolar tailings contain some 6,000 tons of scheelite at 0.3 to 0.5 percent WO_3. The Bankura deposit contains 56,700 tons of ore grading 0.05 to 0.06 percent WO_3 and 32,970 tons grading 0.01 percent WO_3.

Two alluvial mines, one in West Bengal and one in Rajasthan, are operating currently, utilizing the labor-intensive gravel pump technique. Production of tungsten concentrate in 1981 was 37,738 kilograms (83,212 pounds) compared with 45,793 kilograms (100,974 pounds) in 1980.

Antimony and Asbestos

The known reserves are at the Bara-Shigri Glacier in the Lahauli-Spiti area of Himachal Pradesh, in the Udaipur district of Rajasthan, the Chameli district of Uttar Pradesh, the Karimnagar district of Andhra Pradesh, and the Chitradurga district of Karnataka. To date, commercial extraction has not been economically possible. The Lahauli-Spiti reserves are 10,588 tons, of which a total of 3,296 tons are primary antimony mineralization containing 2.88 percent antimony, and of which 7,292 tons are polymetallic mineralization containing 1.09 percent antimony, 1.4 percent lead, and 0.4 percent zinc.

The only existing producer, the Star Metal Refinery in Bombay, produced as much as 517 tons from imported ore in 1973. The plant was closed in 1979, a year in which it produced just 86 tons. Its installed capacity is 1,000 tons. The current demand for antimony is about 1,500 tons per year, but this is expected to increase to 2,800 tons by 1985. In view of growing demand, the government has decided to set up an antimony producing unit.

Asbestos is found mainly in Rajasthan, Andhra Pradesh, Bihar, Karnataka, and Gujarat states, in that order of importance. Chrysotile has been located in Anantapur, Cudappah, and Kurnool districts of Andhra Pradesh, and in the Singhbhum district of Bihar. The main production centers are Pulivendla, in Cudappah, and Revoburu near Chaibassa, Bihar.

Reserves of all grades are estimated to be 774,815 tons, of which 11,607 tons are proven, 54,304 tons are indicated, and 708,904 tons are inferred. Production of chrysotile is only nominal, at a little over 3,500 tons per year, while the average production of amphibole is a little over 24,000 tons. Total production in 1980 was 31,416 tons, falling to 24,515 tons in 1981.

There are some 200 mines operating, of which only 35 produce more than 200 tons each. With the exception of seven underground mines, they are all open pit mines operating at depths down to just 30 meters (98.4 feet), and all of the underground operations mine chrysotile. There is, however, only one mill, operated by Hyderabad Asbestos Ltd., in Andhra Pradesh. Domestic consumption

OFFICER EXAMINING packet of diamonds at the Panna district mines of Madhya Pradesh.

amounts to well over 60,000 tons a year, requiring some 30,000 tons to be imported each year.

Gold

Gold mining on a regular commercial basis began just over a century ago when the Kolar Goldfields were first opened. The main gold-bearing area is the Kolar schist belt, which is believed to be 80 kilometers (50 miles) long, although only 8 kilometers (5 miles) have been fully developed. Bharat Gold Mines Ltd., an Indian government undertaking, operates the mines here. The other area is that worked by Hutti Gold Mines Company Ltd., a Karnataka State government undertaking. Both are in Karnataka State.

Reserves of gold ore are estimated to be 4,467,940 tons. The GSI has now discovered additional gold prospects in the Mallappakonda and Chigargunta Hill areas of Chittoor district, Andhra Pradesh. Reserves are estimated to be 310,000 tons at 5 grams (0.16 ounce) of gold per ton, over a width of 2.2 meters (7.2 feet) and to a depth of 100 meters (328 feet). The GSI has also expressed the view that the following areas can all be mined for gold economically: the Betrayswamy and Manighatta blocks in the Kolar schist belt; the contiguous areas in Hutti and Gadag goldfields, particularly Grey's Shaft at Hutti; the Nilambur river valley in Kerala; the Yeppamana and Ramgiri mines in the Anantapur district of Andhra Pradesh; the Singhbhum district in Bihar; and the Keonjhar district in Orissa. It is thought that the Yappamana mines could yield some 345 kilograms (11,092 ounces) of gold per year. Experts also believe that the gold reefs in the southern extension of the Kolar Goldfields may extend into Tamil Nadu and, therefore, the Maharajgarta area in Dharmapuri district would be a good exploration target.

The Kolar Goldfields and Hutti mines together produced only 2,512 kilograms (80,761 ounces) of gold in 1980 and 2,485 kilograms (79,893 ounces) in 1981. At Kolar, a plant has been built to treat 250 tons of tailings per day to recover scheelite, at 40 tons per year. Another plant is being built to recover scheelite from run-of-mine ore. Proposals have also been put forward to install similar plants at Hutti and Ramgiri mines.

Gemstones

The only diamond mining area today is the Panna district of Madhya Pradesh, at the Majhgawan mines and the nearby Ramkheria alluvial deposit. While total reserves are estimated to be 1,200,000 carats, to a depth of 100 meters (328 feet), reserves at Majhgawan mines are 398,200 carats, to a depth of 20 meters (65.6 feet). The reserves of the alluvial deposits are estimated to be 201,000 carats, where the grade is 10 carats per 100 tons. The mines of the Panna district produced 14,140 carats in 1980 and 15,717 carats in 1981.

In the past, diamonds were mined at the famous Golconda mines in Andhra Pradesh. The GSI is involved in exploration in the area to investigate the possibility of reintroducing diamond mining. Diamonds have been located at Vajra Karur near Anantapur, in Andhra Pradesh, where six Kimberlite pipes have been identified. The largest of them, 100 to 200 meters (328 to 656 feet) in diameter, has the greatest potential. The GSI is also exploring in the Hinota and Angor areas near Panna. The Mineral Exploration Corporation is investigating the Munimadagu and Chittoor areas of Andhra Pradesh, the Jugal area of Uttar Pradesh, and Hinol in Madhya Pradesh.

Emerald production in the country is on the decline. Production in 1975 was 38,280 carats, falling to 6,606 carats by 1980. The only known emerald belt runs for 200 kilometers (124 miles) between Ajmer and Udaipur in Rajasthan.

Gem quality garnet is only found in Rajasthan, while abrasive grades are found in Tamil Nadu (mainly recovered from beach sands), Karnataka, and Rajasthan. Total reserves are estimated to be 186,300 tons. Production of gem garnet was 4,251 kilograms (9,374 pounds) in 1980 and production of the abrasive grade was 4,505 tons.

Maharashtra produces 80 percent, Madhya Pradesh 12 percent and Karnataka 8 percent of the corundum and sapphire mined in India. Production in 1980 was 1,574 tons, domestic consumption being about 500 tons. The main deposits are in the Bhandara district of Maharashtra, Rupra in the Sidhi district of Madhya Pradesh, and the Hassan district of Karnataka. Other deposits are found in the Tonk district of Rajasthan and Sonapahar in Meghalaya. Total reserves are recorded as 946,000 tons. A total of 13 mines are in production, mainly shallow open pits. No regular mining for sapphire is being carried out at present, although some 66,700 grams (2,134 ounces) were recovered from debris in Jammu and Kashmir in 1977. The search for sapphire is concentrated on pegmatite veins in the Paddar area.

Agate is found only in Gujarat and Rajasthan. Production was 1,320 tons in 1980. Jasper is found in the Jodhpur district of Rajasthan, where 3,976 tons were produced in 1980.

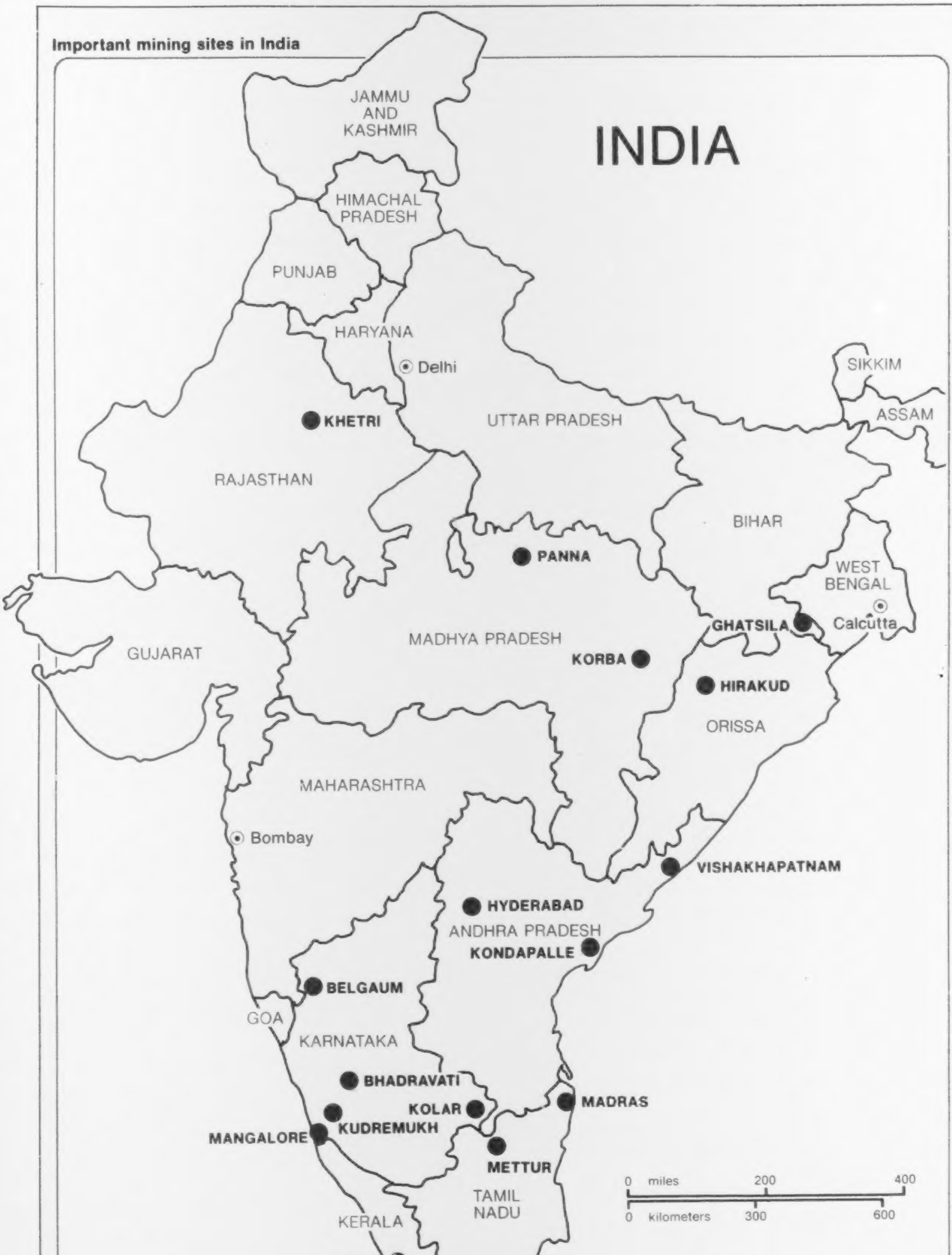
The current production and reserve figures, where available, for other minerals produced in India are outlined in Table 1. When considering the country's barite reserves, note that these figures include the Mangampetta deposit in the Cudappah basin, Andhra Pradesh. The reserves here contain 75,000,000 tons, about 20 percent of the world's identified resources. This is said to be the largest bedded deposit in the world. ■

Table 1.
Other Indian Mineral Products Production and Reserves in Metric Tons

Mineral	Reserves	Production 1980	Production 1981
Apatite	4,660,000	21,731	N.A.
Rock Phosphate	139,400,000	N.A.	N.A.
Phosphorite	14,140,000	541,321	540,000[1]
Barite	83,000,000	405,175	353,362
Bentonite	135,000,000	120,000[1]	120,000[1]
Calcite	681,000	31,420	N.A.
Coal	109,100,000,000	109,102,000	122,478,000
Lignite	4,000,000,000	4,549,000	5,909,000
Dolomite	4,064,000,000	2,017,543	1,954,868
Feldspar	1,740,900	57,524	N.A.
Fireclay	358,980,000,000	716,024	N.A.
Fluorite	12,500,000	21,207	22,905
Fuller's earth	280,000,000	15,000[1]	15,000[1]
Graphite	172,897,550	54,786[2]	56,249
Gypsum	1,205,000,000	839,838	943,316
Kaolin	710,286,866	437,108	505,745
Ball clay	N.A.	119,261	N.A.
Kyanite	152,000,000	50,393	38,283
Magnesite	524,000,000	368,465	453,410
Mica	238,000,000	7,835	8,377
Pyrite	141,237,000	90,469	57,598
Sillimanite	343,000	15,308	10,254
Steatite	15,000,000	314,420	329,149
Vermiculite	256,000	3,153	N.A.
Wollastonite	121,000,000	4,253	15,940

1. Estimated. 2. Run-of-mine. 1.0 metric ton = 1.1 short tons. 1.0 short ton = 0.0907 metric ton.
N.A. = Not Available.

Important mining sites in India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JULY 1982

Special Report:

CONVEYORS IN MINING

A look at technology, equipment, and future trends

JULY 1982
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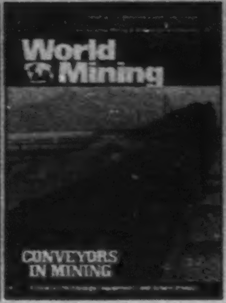

THE COVER

Conveyor belt systems are becoming increasingly popular, whether they wind through miles of open countryside or underground. This month, World Mining takes a look at the many aspects of conveyors in a *Special Report*.

Special Report: CONVEYORS IN MINING

Conveyor Belts Make Sense **C3**

Conveyor belt haulage is becoming ever more attractive to miners throughout the world. Victor Cabrera studies conveyor belt technology in great detail in the first featured article of this Special Report, which begins immediately following the Reader Inquiry Card

What's New in Conveyor Equipment **C17**

As conveyors gain wider acceptance, it becomes imperative that equipment is constantly upgraded. Here is a look at the latest developments

Beltcon **C30**

John Chadwick attended a symposium in South Africa that was devoted exclusively to conveyors—their design, operation, and optimization

Keeping Belts Clean **19**

Operating costs can be kept down if conveyor belt systems are kept clean. J. C. Leroy examines the many ways that this can be accomplished

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An unconventional method is being used by this Malaysian company in building a new dredge. John Chadwick has the story

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Optimism was evident at this conference, one of the most important in the world. There was also good information on the latest technology

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Changing economics and technological advances have made conveyor belt haulage more attractive to both hard rock and coal mining operations throughout the world

Conveyor belts make sense for long distance haulage

By **Victor Cabrera**
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The dramatic increase in fuel oil prices, together with the double digit inflation of recent years, has significantly raised the cost of mine haulage. In addition, the deepening of the open pits due to ore and waste extraction and the associated longer hauls against adverse grades have contributed to the increased cost. Continuous advances in truck technology, including larger payload capacity, electric wheels, and improved drive trains, have been unable to offset these changes, which will force ever larger truck haulage costs in the future.

According to the Conference on Productivity in Mining, sponsored by the University of Missouri-Rolla, Pennsylvania State University, and the University of Arizona in 1974, the haulage of ore to the plant and waste and overburden to the dumps accounted for 45 percent of the average cost for metalliferous surface mining at that time[1]. These same costs can be extrapolated to coal mining. Therefore, a major target for productivity improvement is a haulage system that can run reliably with fewer operators and less maintenance than is required with trucks.

[illegible]

Table 1. Mine truck operating and cost: summary data

Year	Average truck capacity (tons)	Cost per ton-mile (cents)	Average haul distance (miles)
1965	64.4	7.2	1.18
1967	71.3	10.3	1.37
1969	78.6	9.9	1.42
1971	78.7	11.2	1.41
1973	81.7	9.6	1.53
1981	90.0	12 to 18	1.70

Data for 1965-1973 obtained from reference number 1.
Data for 1981 based on limited field data from open pit mines in Arizona, United States.

The operating costs in non-escalated dollars for several major hauling truck fleets are shown in Table 1. When all costs in Table 1 are escalated to 1981 dollars, the greater cost efficiency of the current larger capacity trucks is obvious. In spite of this increased efficiency, recently installed in-pit medium distance conveying systems have decreased the corresponding truck haulage costs by half.

The long distance belt conveyor, also called the overland belt conveyor because it follows the contour of the terrain, is becoming commonplace for the transport of coal and lignite from mines to power plants in the United States, West Germany, the Soviet Union, and other countries. Large iron ore and porphyry copper mines have also followed this lead. Cement raw materials, bauxite, and nickel ores are being handled with belt conveyors. Conveyors have also been used in land reclamation, dam construction, and highway projects. With the overland conveyor, engineers have found a mature technology that is low in cost, energy efficient, and requires few skilled operators to move large quantities of bulk material over long distances.

The recapture of the favorable productivity trends of the past is imperative for the survival of the surface mining industry. This endeavor becomes attractively realistic as creativity is applied to haulage systems such as belt conveyors.

What are the Advantages?

The troughed belt conveyor dates back to 1891, when the first true belt conveyor was installed in the Ogden iron ore mine in New Jersey, United States. Thomas A. Edison, the inventor who pioneered so many other developments, assisted in the design of the troughing idlers, which were necessary to carry large loads. Since that time, continuous technological advances in conveyor components, such as pulleys, bearings, and belting, have made possible the modern high-speed, heavy-duty units used in today's large capacity conveyors.

The economic advantages of belt conveyors over truck and rail transport arise from the following factors:

- Because grades of up to ± 30 percent may be attained by belt conveyors without loss of efficiency, haul distances are much shorter than for road or rail. By comparison, the recommended limiting grades are ± 10 percent for trucks and ± 2 percent for rail. Therefore, longer road and track distances are required.
- The overland conveyor is normally installed at ground level, which involves light foundations with a minimum of support structures.
- Belt conveyors easily cross roads, railways, waterways, and other obstructions on light bridge-type supports.
- Long single flight belt conveyors are possible with the use of high strength steel cable belting.
- Unlike trucks, conveyors have a relatively uniform electrical demand, which may be derived from a non-oil based power plant, such as coal, hydro, or nuclear. Downhill conveyors may produce regenerative electric power instead of dissipated heat, which is common to truck and rail haulage braking assemblies. In addition, the power requirements may be reduced by balancing uphill and downhill runs of the conveyor.
- Preventive maintenance which is designed to reduce equipment wear can lead to low overall maintenance costs. As a result, spare parts inventories are minimized.

Today more than ever belt conveyors are being called on to serve in rugged applications involving longer distances and greater lifts. Both overland and inplant conveyors are now handling capacities that in the past were considered unrealistic. With the development of steel cable reinforced belts, capacities of 20,000 tons per hour with single lengths of 2 miles (3.2 kilometers) for hard rock haulage are both possible and economical. Cable belt conveyors carrying 3,000 tons per hour on a single five-mile (8-kilometer) flight are currently in use in the coal industry.

Many Mines are Switching

Cost-conscious mine operators are making greater use of belt conveyors and cable belt conveyors as design improvements and increases in belt speed and capacity make them economically competitive with traditional truck and rail haulage. Conveying speeds have risen to 1,200 feet per minute (6 meters per second), belt widths to 10 feet (3 meters), with increaed total haul distances to 62 miles (100 kilometers). Typical examples of the latest applications of belt conveyors in hard rock and coal mining are described below.

Underground coal mines in the United States and other mines with bedded deposits, such as potash, use belt conveyors extensively. The continuous underground haulage system includes inclined conveyors running to the surface and longitudinal conveyors to a vertical shaft equipped with a skip hoist system to bring ore to the surface. The combination of belt conveyors and skip hoists in underground haulage is less vulnerable to rising fuel, labor, and equipment costs than conventional mine rail and trackless haulage.

One such conveying system in the hard rock industry is located at Noranda's Lakeshore mine in Arizona. The 7,800-foot (2,380-meter) long system is designed to carry 1,300 tons per hour of crushed ore from a 2,000-foot depth up a constant 15° ramp to the surface.

Because haulage of ore, waste, and overburden constitutes almost half of surface mining expenses, the capability to transport large tonnages of material at increasingly lower unit costs is vital to the profitable operation of many of these mines. The biggest potential for the use of high capacity belt conveyors is in the large open pits, which over the years have gone deep enough to make the upgrade truck haulage of ore and waste prohibitively expensive. The belt conveyor becomes an attractive substitute for truck fleets, in order to help counteract declining ore grades and the inflationary pressures of fuel oil, equipment, and labor prices.

Along with in-pit belt conveyors, development in the future calls for the use of heavy-duty, high capacity, in-pit crushers to provide sized material for large-scale belt conveying from the pit. These crushers may be stationary or semi-portable to fit the particular planning needs. As part of a portable crushing system, a series of movable conveyors

CONVEYORS and bucketwheel excavators in use at brown coal mine in West Germany.

will transport the ore to fixed inclined conveyors for out-of-pit haulage. In recent years, two Arizona copper mining operations have acquired in-pit conveyor systems for both ore and waste. These systems typify the state of the art in belt conveyor haulage.

The average daily mine output of Duval Corporation's Sierrita in-pit conveyor system is 250,000 tons, 110,000 tons of which are ore for the concentrator. The new conveyor system has reduced the number of trucks from 24 to 14 per shift and has cut overall energy consumption per ton moved.

Duval's ore haulage system consists of an in-pit 60 by 89-inch (1.5 by 2.26-meter) gyratory crusher, feeding minus-6-inch (minus-150-millimeter) ore to a 16,000-foot (4.9-kilometer) long system of 60-inch (1.5-meter) wide belt conveyors with an overall lift of 540 feet (165 meters) and a connected power of 12,850 horsepower. The waste disposal system has two 60 by 89-inch (1.5 by 2.26-meter) gyratory crushers feeding 7,000 feet (2.1 kilometers) of 60-inch (1.5-meter) wide conveyors, with an overall lift of 436 feet (133 meters) requiring 7,600 connected horsepower.

Mine Overland Conveyors

In 1978 the new Eisenhower mine, jointly owned by Anamax Mining Company and Asarco Inc., commissioned an overland belt conveyor haulage system, which is a radical departure from the conventional steel belt conveyor (where the belt carries the tension load). In this system, the driving tension is applied through two endless wire ropes, while the belt acts only as a carrying medium. Called a cable belt conveyor, it was manufactured by Cable Belt Ltd., of the United Kingdom. Engineering economy studies to select the most appropriate haulage system for ore converged on belt conveying because of its moderate capital cost, higher availability, and lower operating cost than truck or rail haulage.

The Twin Buttes belt system includes one 54 by 80-inch (1.37 by 2.03-meter) gyratory crusher, capable of producing 2,000 tons per hour of minus-6-inch (minus-150-millimeter) material. The cable belt overland conveyor is 32,513 feet (9.9 kilometers) long, 42 inches (1.05 meters) wide, has a velocity of 824 feet per minute (4.2 meters per second), with an overall lift of 50 feet (15 meters), and with connected power of 2 x 1,500, or 3,000 horsepower. One ingenious feature of this belt conveyor is a 60° horizontal bend located 2,700 feet (823 meters) from the loading point. At this point, the material flow changes direction by transfer to a second conveyor flight. However, the same driving ropes are used by changing their direction through the use of sheaves. Thus, only one drive is required for both conveyors.

Energy Materials: The heaviest use of high tonnage conveyors has been in the brown coal fields of West Germany. At the Fortuna mine, for example, 16,000 tons per hour are transported in 87-inch (2.21-meter) wide conveyors at a speed of 1,000 feet per minute (5.2 meters per second). New coal mines in the western United States and Canada are following this pattern with success for coal and tar sands mining.

Iron ore: Several iron ore shiploading operations in the United States, Canada, Brazil, and Australia have individual belt conveyors rated at 20,000 tons per hour. These high capacity conveyors work in conjunction with matching capacity bucketwheel excavators and reclaimers. High capacity belt conveyors are the centerpieces of modern superports for loading and unloading coal and iron ore for world trade.

Where are Conveyors Suitable?

Many surface mines have substantiated the technical and economical advantages of belt conveyor haulage over truck and rail. New mines with substantial tonnages of ore and waste and with medium distance hauls, in the range of about 2 miles (3.2 kilometers), are well advised to consider belt conveyor haulage for their projected operations. It is also timely for established open pit mines with aging truck fleets to look again at belt conveyors for their ore and waste haulage. The lower mining cost afforded by belt conveyors, as opposed to truck and rail haulage, will enhance the profitability of their operations.

Conveyor haulage has certain limitations for its appropriate application. Some of these items are listed below.

- The bulk material should preferably be sized to eliminate large lumps. Therefore, some means of crushing the feed, to say minus-6 to 8-inch (minus-150 to 200-millimeter) size is required. This has led to the current acceptance of in-pit crushers and breakers to size most hard rock and coal.
- The material should not be either too wet or too dry. Maintenance costs to clean pulleys, idlers, and belting increases with wet, muddy materials. The wet material also tends to backslide on the belt carrying surface, due to the low friction at the water film/particle interface. Therefore, ideally, the material should hold its moisture without visibly releasing water during conveying.

Bone dry and dusty materials produce losses at transfer points with associated clean-up and maintenance problems for the moving parts of the conveying equipment. The low friction between the bone dry material and the carrying side of the belt, especially at high conveying speeds, may cause the load to backslide, producing unexpected spills. This condition is readily corrected by lightly spraying the ore as it is fed

OVERLAND CONVEYORS contrast to rail transport and haul over 30 percent grades.

onto the conveyor.

- On the horizontal plane, the conveyor route should be run with straight line belt conveyors, preferably with one flight or a minimum number of flights. Although angled and curved conveyors are in existence, they are somewhat more costly and difficult to maintain than straight flight conveyors.
- The operational reliability of the belt conveyor is increased with the smaller number of flights. The smaller number of transfer points and drives minimizes the incidence of trouble that might interrupt the total handling operation. For example, if the reliability of a single flight conveyor is 0.95, then that of six flight conveyors is reduced to 0.95^6, or 0.74. It should be noted that a known six-flight system has achieved a 0.90 reliability, which implies a single flight reliability of 0.98.
- Overland conveyors may contain several vertical curves limited to slopes of ±30 percent to conform with the natural ground profile. This feature minimizes the costs of support structures and provides an esthetic low profile.
- The higher the belt speed, the greater will be the handling rate and economy of the conveyor system. Belt speeds of 1,000 to 1,200 feet per minute (5.1 to 6.1 meters per second) are possible today. Economical belt widths vary from a minimum of 36 inches (900 millimeters) up to 72 and 84 inches (1.8 and 2.1 meters). Minimum operating costs are obtained by the steady and continuous use of the conveying system throughout the year with on-the-run preventive maintenance. The system should stop only for major scheduled maintenance.
- The continuous operation of the belt conveying system requires redundancy of equipment and controls. For example, the multi-unit drive should have one standby unit to press into service while removing a unit in need of repair or maintenance. Changing idlers does not require belt stoppage, and paralleled controls and instrumentation ensures their operation even if some individual element fails to function.

Conveyor Design—Calculations

The objective of a belt conveying system is to haul a given bulk material, such as hard rock or coal, at a certain capacity expressed in tons per hour, from feed Point A to discharge Point B. The preliminary conveyor design calculations should enable the engineer to select the conveying system for planning and budgeting purposes. The detailed design of the system that follows this preliminary calculation is the subject of specialized computer programs and formal calculations, which are too lengthy for the purpose of this article.

Conveyor layout: It is necessary to define the conveying system and Points A and B in a topographic map in order to select the most convenient route. This may be one single straight line conveyor, or several straight line flights may be necessary to adapt the conveying route to the traversed ground. Natural and man-made obstacles, such as rivers, canyons, canals, highways, and rail lines are crossed and cleared by belt conveyors supported by light bridge-type structures. The present distance limitation for single flight conveyors is about 10 miles (16 kilometers). Vertical slopes may range from +30 to -30 percent from the horizontal (±16° inclination). Table 2 provides belt capacity in tons per hour at a belt velocity of 1 foot per minute (5 millimeters per second) for various belt widths, and may be used for preliminary calculations.

Given the tonnage per hour and bulk density, the volume to be conveyed is found as follows:

Volume (cubic feet per hour)
= tons per hour x 2,000 pounds per ton
÷ pounds per cubic foot
or
Metric volume (cubic meters per hour)
= (metric tons per hour
x 1,000 kilograms per metric ton)
÷ kilograms per cubic meter

The volume divided by the selected belt speed, say 800 to 1,100 feet per minute, will provide the belt capacity required in cubic feet per hour for a velocity of 1 foot per minute. These figures are compared in Table 2 to select the matching belt width.

Parameters for bulk materials handling: The following parameters are necessary for conveyor calculations with illustrative examples.

- *Material:* Coal, iron ore, copper ore, limestone, etc. Example: crushed rock
- *Bulk density:* 106 pounds per cubic foot (1.7 metric tons per cubic meter)
- *Size:* Minus-8-inch (minus-200-millimeter)
- *Moisture:* 8 percent
- *Abrasiveness:* Medium

- *Surcharge angle:* 20°, Class B. Most rock and coal material belongs to this class. Class A is free-flowing material. Class C is fibrous, stringy material.
- *Operating conditions:* Required capacity, 18,000,000 tons per year; operating time, 6,000 hours per year; nominal conveying capacity, 3,000 tons per hour; conveyor route distance, 4 miles with 100-foot lift.

Belt conveyor sizing: For a given speed, belt conveyor capacities increase with the width of the belt. Belt widths are standardized with increments of six inches (36, 42,...84 inches). Belt speeds should be the maximum possible within design limitations in order to minimize capital cost.

The cross-sectional area formed by the material as it rides on the belt is a function of the belt width, the belt troughing angle, and the material surcharge angle. Overland conveyors have troughing idlers inclined at 30 or 35°. Conveyors with multi-roll garland idlers and the cable belt conveyor allow the belting to adopt a catenary profile. In this case, the cross-sectional area is greater than that formed by a conveyor equipped with fixed troughing idlers.

The volumetric capacity of the conveyor is as follows:

Volume per hour
= (3,000 tons per hour
x 2,000 pounds per ton)
÷ 106 pounds per cubic foot
= 56,600 cubic feet per hour

If we assume a belt speed of 1,000 feet per minute, the volumetric capacity of the belt will be:

Volume per hour
per foot per minute speed
= 56,600 cubic feet per hour
÷ 1,000 feet per minute
= 57 cubic feet per hour
per foot per minute speed

Then, according to Table 2, the selected belt width will be 36 inches.

Belt conveyor drive: The horsepower (HP) necessary to drive a belt conveyor is a function of the effective tension (Te), in pounds or kilograms, at the drive pulley(s) to propel or restrain the loaded belt; and the belt velocity (V), in feet per minute or meters per second.

HP = Te x V ÷ 33,000
when Te = pounds, and V = feet
per minute
HP = Te x V ÷ 76
when Te = kilograms, and V = meters
per second

The belt effective tension (Te) is the sum of several factors, which for preliminary calculations should be considered as follows:

- Friction of the transported material and belt as it flexes over the idlers. Use a friction factor of 0.025.
- Gravitational load to lift or lower the transported material and belt. Use the elevation difference between terminal points.
- Friction of conveyor rotating elements. Use an approximate value of 3 pounds per carrying idler.

Secondary forces that should be included in the more detailed calculation of the belt effective tension include skirtboard friction, acceleration of the load on start-up, temperature correction, etc. Analytical treatment of all forces acting on the belt drive are contained in numerous computer programs and are also described in trade and manufacturers' publications.

Therefore, the effective tension (Te) can be expressed according to the following simplified formula:

Te = friction of material and belt
± gravity load
+ friction of rotating parts,
where
Friction of material and belt
= friction (m + b).

The material weight per unit length of conveyor is as follows:

Unit weight material
= (3,000 tons per hour
x 2,000 pounds per ton)
÷ (60 minutes per hour
x 1,000 feet per minute)
= 100 pounds per foot

The unit weight of the belt could be approximated to be 3 to 9 pounds per foot of belt width, the higher values being for steel cable belts. Select 7 pounds per foot.

Unit weight of belt
= 7 pounds per foot x 36-inch width
÷ 12 inches per foot
= 21 pounds per foot
Friction factor = 0.025
Distance = 4 miles.

Therefore, the friction load for material and belt load is as follows:

Friction (m + b)
= 0.025 x (100 + 21) pounds per foot
x 4 miles x 5,280 feet per mile
= 0.025 x 121 x 21,120
= 64,000 pounds
Gravity load
= ± Height difference x unit weight
Height difference in feet or meters
Unit weight of material plus belt
as per above in pounds per foot
or kilograms per meter
Gravity = 100 feet x (100 + 21) pounds
per foot
= 12,000 pounds

Table 2. Rate of material flow at belt speed of 1 foot per minute'

Belt Width inches (millimeters)	Cubic feet per hour	Cubic meters per hour
30 (750)	40	1.13
36 (900)	59	1.67
42 (1050)	82	2.31
48 (1200)	108	3.06
54 (1350)	139	3.92
60 (1500)	173	4.89
72 (1800)	252	7.13
84 (2100)	346	9.80

1. 35° Idlers with Equal Length Rolls
20° Material Surcharge Angle

Friction of rotating parts: For heavy-duty purposes, the resistance per idler is less than 3 pounds. The troughing idler spacing is 5 to 10 feet, the latter for high tension belts. Assume carrying idler spacing is every 8 feet.

Friction of rotating parts
= 3 pounds per 5 to 10 feet

Therefore, the load of rotating parts is as follows:

Friction of rotating parts
= (3 pounds per idler
÷ 8 feet per idler)
x (6 miles x 5,280 feet per mile)
= 12,000 pounds

Thus, the conveyor power will be

HP = Te x V
÷ 33,000
= (88,000 pounds
x 1,000 feet per minute)
÷ 33,000
= 2,700 horsepower
Where Te = (64,000 pounds
+ 12,000 pounds + 12,000 pounds)
= 88,000 pounds
and V = 1,000 feet per minute.

Coal conveyor example: The XYZ Coal Company plans to haul 18,000,000 tons of coal per year from the mine face to the stockpile of a power plant located 6 miles away. The difference in elevation makes necessary a lift of 105 feet.

The preliminary data on material, operating conditions, and conveyor route are as follows:

Material: Mine run coal

Bulk density: 50 pounds per cubic foot (801 kilograms per cubic meter)

Size: Minus-6-inch (minus-150-millimeter)

Moisture: 8 percent

Abrasiveness: Mildly abrasive

Surcharge angle: 20°, Class B

Operating conditions:

Working days: 250 per year
Operating time: 22 hours per day
Daily capacity: 72,000 tons
Hourly capacity: 3,273 tons
Design capacity: 1.25 x 3,273
= 4,100 tons per hour x 0.91
= 3,700 metric tons per hour

Belt sizing: The volumetric capacity of the conveyor is as follows:
Volume = (4,100 tons per hour
x 2,000 pounds per ton)
÷ 50 pounds per cubic foot
= 164,000 cubic feet per hour
Metric volume = (3,700 tons per hour
x 1,000 kilograms per ton)
÷ 801 kilograms per cubic meter
= 4,620 cubic meters per hour

Assumed belt speed is 900 feet per minute (4.57 meters per second).

The volume per unit belt speed is:
Cubic feet per hour
per feet per minute speed
= 164,000 cubic feet per hour at 900 feet per minute
= 182 cubic feet per hour
per foot per minute

The 72-inch belt width is adequate for this service (see Table 2).

Belt conveyor drive: The route study indicates that it is possible to have one single belt conveyor flight following the ground between the mine face feed point and delivery to the power plant stockpile.
Horizontal distance
= 6 miles (9.65 kilometers)
Difference in elevation
= 105 feet (32 meters)

The calculation of the effective tension (Te) is:
Friction of material and belt (friction factor = 0.025)
Weight of material
= (4,100 tons per hour
x 2,000 pounds per ton)
÷ (60 minutes per hour
x 900 feet per minute)
= 152 pounds per foot (227 kilograms per meter)
Weight of belt
= 8 pounds per foot
x 72 inches (6 feet)
= 48 pounds per foot (71 kilograms per meter)
Belt length
= 6 miles x 5,280 feet
= 31,680 feet (9.65 kilometers)
Total friction
= (152 ÷ 48) pounds per foot
x 31,680 feet
x 0.025
= 158,400 pounds *(1)*
Total friction (metric)
= (227 ÷ 71) kilograms per meter
x 9,650 meters
x 0.025
= 71,900 kilograms *(1)*
Gravity load
Lift load = 105-foot lift
x (152 + 48)pounds per foot
= 21,000 pounds *(2)*
Lift load (metric)
= 32-meter lift
x (227 + 71)kilograms per meter
= 9,500 kilograms *(2)*

Friction of rotating parts: Assume the troughing idler spacing is 6 feet (1.8 meters) and resistance of friction per idler at 3 pounds (1.4 kilograms).
Friction load
= 3 pounds ÷ 6 feet
x 31,680 feet
= 15,900 pounds *(3)*
Friction load (metric)
= 1.4 kilograms ÷ 1.8 meters
x 9,650 meters
= 7,500 kilograms *(3)*

We add *(1)*, *(2)*, and *(3)* from above to find the effective tension (Te).
Te = 158,400 + 21,000 + 15,900 pounds
= *193,300 pounds*
or 71,900 + 9,500 + 7,500 kilograms
= *88,900 kilograms*

The power for this drive is:
HP = Te x V ÷ 33,000
= 195,300 pounds x 900 feet per minute
÷ 33,000
= *5,330 horsepower*
HP (metric) = Te x V ÷ 76
= (88,900 kilograms
x 4.57 meters per second)
÷ 76
= *5,330 horsepower*

Therefore, the power drive for this belt conveyor (after considering drive efficiency and accessory loads) will be about 6,000 horsepower, which could be divided into five modules of 1,500 horsepower each, four operating and one spare.

What's New in Conveyors?

The basic design concepts of components for medium and long distance belt conveyors were established during the development of in-plant use. These have been continuously refined and improved for present-day applications. Let us examine the following major changes:

New belt materials: New belt materials in use today enable the engineer to use light belts with improved strength. The improvements allow deeper troughing to carry the load and allow greater distances between idlers and between terminal points than ever before.

While the belt tension rating of multi-ply fabric carcass belts can reach 700 to 1,000 pounds per inch of belt width (PIW), the steel belts are rated several fold higher to 6,000 PIW (working strength). One method of keeping steel cable belt tensions at a minimum is to divide the total drive horsepower into several drive pulleys in series. These drive pulleys, normally located at the head end or tail end of the belt conveyor, are intended to increase the amount of belt wrap, thereby decreasing the tension required to drive the belt without slippage. Each drive pulley could be equipped with a drive train consisting of a motor, reducer, coupling, etc., at each end of the pulley shaft.

The belt covers are usually made of vulcanized rubber, which is resistant to gouging and abrasion. The wear or top cover is thicker than the non-wear bottom cover. However, some steel belts with usable thick covers for wear on both sides could theoretically double the belt life. Belt cover materials resistant to oils and high temperature include neoprene, propylene rubber, butadiene rubber, urethane, and other synthetics. These belt covers find application in handling tar sands, oil shale, and corrosive materials.

A radical departure from steel belts is the cable belt conveyor, where the tension member is outside the troughing belt. Two parallel grooves located near the edge of the belt are grip-attached to two parallel endless woven wire cables, which are driven as hoist cables. The weight of the load causes the belt to adopt a catenary shape. Single or multiple drives are used in cable belts in accordance with friction rope hoisting technology. Due to the large tension capability of both steel belts and cable conveyors, the maximum length per single flight may reach 10 miles (16 kilometers), with the conveyor crossing peaks and valleys, adapting to the contour of the terrain.

Idlers: Conventional three-roll troughing idlers for overland conveyors normally have their outer rolls angle 30 to 35° from the vertical. A greater angle, say 45°, achieves greater cross-sectional area and therefore, greater capacity for the same width of belt. However, rather than conforming to the idler shape, a catenary form is induced by the material weight, with most of the load being car-

CONVEYORS
IN MINING

DIFFICULT TERRAIN is traversed by conveyors, avoiding expensive truck haulage.

ried by the outer rolls. The search to remedy this condition has led to the development of the multiple roll idler, with a flexible chain link connection, known today as the garland idler.

In a further departure from the rigid steel structure idlers, the latest garland idlers are slung from a steel cable, which is in turn suspended from rigid supporting stands. This so-called "suspended garland system", equipped with anti-friction bearings, permits intervals of 16 to 20 feet (5 to 6 meters).

Wear resistance and self-cleaning has been achieved with urethane-covered rollers. Improved lubrication for idler bearings has reduced power needs and the cost of idler maintenance.

In the cable belt conveyor system, the support pulleys are spaced 16 to 20 feet (5 to 6 meters) apart. These pulleys, mounted on sealed ball bearings, are lined with a polyurethane tread on which the driving rope rides. The reduction in the total number of bearings in the system plus the elimination of flexure over standard idlers makes possible a 20 to 30 percent reduction in power requirements, compared with an equivalent conventional system.

Drive systems: High capacity overland belt conveyors require powerful and reliable drive systems. The high torques and shock loads normally encountered when squirrel cage motors are started are unacceptable because they can easily overstress and damage the belting and drive system components. It is therefore essential that the drive system be capable of a "soft start".

The "soft start" can be obtained by a number of readily available methods. The wound rotor induction motor utilizes controlled acceleration through incremental steps of secondary resistance until full belt speed is achieved. This is the most widely used method and has been successfully applied to large overland conveying systems.

A variable speed system utilizing squirrel cage induction motors and variable frequency starting has been applied to an in-plant conveying system in Mexico. In addition to varying frequency, reduced voltage can also be applied to squirrel cage motors at starting, provided the reduced torque at starting can overcome the breakaway static friction of the conveyor. In this regard, the eddy current assembly has a reportedly high rating because of its simplicity and flexibility of control.

Fluid couplings control the torque applied to the load and thereby indirectly control the accelerating time. The fluid coupling is generally used with squirrel cage motors started across the line, and provides a reasonably smooth acceleration if properly designed. Recent attempts for efficient heat dissipation in large fluid couplings include the use of oil-immersed clutch discs, which are squeezed together at precise pressures through a feedback system that transmits the desired "soft start" torque.

All of the previously mentioned drive systems will provide a "soft start". Drive system application must give due consideration to the electric power system, the size of the drive modules, and the availability of qualified maintenance personnel for the particular system.

Pulleys: The proper design and application of pulleys has a significant effect on the conveyor system availability as well as belt training (centered running) and wear.

Pulleys for long distance overland and high tonnage conveyors using steel cable belts are individually engineered to work with the high tensions developed by the system. Particular attention is given to pulley and disc welds, since past failures occurred at stress concentration points, such as hub and disc interfaces. The development of reliable pulleys includes high-strength shafts that maintain hub deflection below critical stresses. Several applications involve the use of pulleys with double drum or with internal disc ribs.

Common pulley design includes lagging the face of all pulleys with rubber to reduce wear of both pulley and belt. Drive pulley lagging is grooved to increase the friction factor and to squeeze water out.

In multi-flight conveyor systems, pulley size and assemblies are standardized to facilitate replacement and to reduce the inventory of spare parts.

Belt cleaning devices: (See a separate article on this aspect, WORLD MINING, July 1982, page 19.)

Belt take-ups: Proper belt tensioning to prevent belt slippage on the drive pulleys is controlled automatically by horizontal rail-mounted pulley trucks that are moved by take-up winches. Calibrated load cells with set limits are used to activate the take-up winch motor, to maintain designed belt tensions for all operating conditions, varying from a fully-loaded to an empty belt.

With cable belt conveyors, both ropes are tensioned equally in spite of differential stretch. This is accomplished by two bogies, which are free to travel on independent trucks, one on either side of the conveyor. The take-ups are usually gravity type with equal weights to provide the same working tension on each rope.

Safety mechanisms: The protection of the belt conveyor requires considerable and continuous atttention through inspection and scheduled maintenance. The check list includes the following:

- Belt anti-rip safeguards
- Braking systems
- Conveyor equipment monitoring

Belt anti-rip devices prevent longitudinal slitting of the belt, which would lead to costly belt replacement and shutdown of operations. To avoid such damage, tramp metal should be completely eliminated from the material flow before it reaches the overland conveyor. This is achieved through the use of metal detectors, magnetic pulleys, or over-belt magnetic separators. Loosened wear plates and bolts are major sources of this problem and it is necessary to thoroughly check feed and transfer points during periodic inspections.

The braking system of overland conveyors is designed to prevent reverse and forward rotation of the drive pulley(s) when power is cut off. Commonly used are the fail-safe mine hoist type brake shoes and drum, which are actuated by counterweights. Another is a fail-safe spring actuated brake, which requires an electrically-driven hydraulic pump to overcome the spring force when power is on. These brakes are an integral part of the drive train, associated with each drive pulley in the conveyor system.

Automatic operation of the overland conveyors requires centralized monitoring and control to properly sequence their start-up and shutdown with upstream and downstream flows of material. The control room usually has a graphic display of the belt conveying system with recording instruments, controls, and alarms for monitoring the system. In addition to registering belt speeds and rates of production, the control panel indicates operating conditions of the drive pulley assemblies, including motors, reducers, fluid couplings, belt tensioning take-ups, braking systems, and ventilation of the switchgear rooms. Closed circuit television is used to visually inspect critical points, including transfer points and belt tensioning systems.

The following is a partial list of overland belt conveyor safety devices:

- Emergency stop with pull cord or stop buttons
- Overspeed detectors for downhill conveyors
- Belt slipping detectors
- Belt anti-rip detectors
- Plugged chute detectors
- Brake trouble detectors
- Motor overload
- Overheating of oil in reducers, fluid couplings, etc.

Conveyor supports and housing: The ability of belt conveyors to follow the ground contour together with their relatively light weight makes savings possible in support structures and protective housings. Shiftable conveyors used for large volume waste handling have modular skid bases to relocate the conveyor without disassembling it. Light bridges are used to cross highways, railroads, rivers, and canyons. The decision to protect belt conveyors from the weather is made according to climate, material handled, and the type of operation.

The spacing of return idlers dictates the location of the support legs to grade. This varies from 40 feet (12 meters) to 70 feet (18 meters) for garland conveyors. Common conveyor supports in use today include continuous channel stringers for support of the idlers with intermediate support legs to the grade, or intermittent stringers of shop-assembled channels and posts, which form a table-like structure that supports the idler assemblies. These support legs may rest on railroad ties or on skid-type bases for shiftable conveyors. Still another conveyor support consists of independent idler stands on concrete footings.

The underground coal mining industry has developed wire rope supports, which have been adapted to tunnel and surface conveyor systems. Overland conveyors use two sets of non-running wire ropes. The first set supports the idlers, belt, and load being transported. The second set carries hood covers, which prevent external loads like snow and wind from imposing on the conveying system proper.

Typical conveyor frames used in mild climates are of mild steel construction with a protective paint finish. For installations located near tidewater and subjected to salty fog or mist, U. S. Steel Corten or its equivalent is recommended. This steel is made resistant to atmospheric agents by a self-protecting thin oxide film, which prevents further oxidation.

Conveyor belt protection against wind, rain, and temperature changes vary from the simple to the quite elaborate. Concrete and steel galleries may completely enclose the conveyor and walkways. On the other hand, complete or partial conveyor covers offer suitable protection against wind and rain. Since the conveyor is often close to the grade, patrolling by pick-up trucks for inspection and maintenance is usual. Also, the conveyor supports may be used as a railing to accommodate a wheeled patrolling car.

Horizontally curved conveyors: One innovation to conveyor system design that is gaining wider acceptance replaces the traditional series of conveyors used for redirecting the flow of material with a single conveyor containing long radius horizontal curves. The curves generally have a radius of ½ to 2 miles (800 to 3,200 meters) and have been applied to single flights of 800 feet to 7 miles (240 to 11,250 meters). Current installations are light to medium-duty with capacities ranging from 200 to 1,200 tons per hour.

A recently installed curve conveyor in New Caledonia, known as the "Curvoduc" system, manufactured by REI, of France, for transporting lateritic nickel ore, follows a 6.8-mile (11-kilometer) long curved route, winding and turning a total of four times (see WORLD MINING, September 1980, pages 42-45). The Curvoduc descends some 1,800 feet (560 meters), with slopes of up to 30 percent. The 31.5-inch (800-millimeter) wide belt carries 560 tons per hour, running at a speed of 710 feet per minute (3.6 meters per second).

Economics of Belt Conveyors

Belt conveyors for long haulage of hard rock and coal are both technically and economically feasible. In the previous pages, the technical advantages of belt conveyors have been presented. However, good engineering judgment has to be justified by its economic appeal. The belt conveyor operation has to be competitive with alternate haulage systems with a lower cost per ton or ton-mile.

Part A below covers the cost analysis of overland "dedicated" long distance belt conveyor systems, which are operating today as planned. These conveyors are reliable, low-cost facilities, since they use electric power from sources other than fuel oil and require less manpower and less maintenance than alternate haulage systems.

Part B provides a typical comparison of belt conveying versus truck haulage for in-pit, medium distance haul, and large tonnage applications. Although several simplifying assumptions have been made, the results are indicative of the economic advantage of belt conveyors over trucks in surface mining.

The growing trend in conveyor haulage of hard rock and coal in surface mines will be accentuated in the future because of its economic advantages. This is especially relevant with the advent of in-pit coal breakers and rock crushers, which produce conveyable material close to the mine face.

A. Cost of Overland Conveyors

In order to show the comparative economics of existing long distance overland haulage conveyors, the following systems are presented in Table 3:

- Hierro Peru's conveyors[2]
- Morocco's Bucraa conveyor[3]
- Anamax's Twin Buttes conveyor[4]

The above are all medium tonnage (±2,000 tons per hour), long distance conveyors with a different cost structure than the high tonnage, medium haul conveyors of open pit mines. An example of the latter is discussed below.

Hierro Peru and Bucraa have steel belt conveyors. Anamax Twin Buttes conveyor has a cable belt conveyor. Both types have gained wide acceptance and are being used extensively for rock and coal haulage around the world.

The cost analysis that is described in Table 3 has been simplified for clarity. The cost summary in 1982 dollars is presented in Table 4.

Table 3. Comparative technical and economic analysis of overland conveyors

Conveyor System Year installed Location	Hierro Peru's Iron ore 1961-1966 Peru	Bucraa Phosphate 1974 Morocco	Anamax's Twin buttes 1976 Arizona, United States
Technical Data			
Length (downhill)	1.60 miles (2.57 kilometers)	—	—
(cross-country)	7.90 miles (12.80 kilometers)	62 miles (100 kilometers)	6.16 miles (9.91 kilometers)
Number of flights (downhill)	4	—	—
(cross country)	4	11	1
Lift (-drop)	-1700 feet	— (520 meters)	50 feet
	-380 feet (-116 meters)	—	15 meters
Material	Iron ore	Phosphate rock	Copper ore
Material density (pounds per cubic foot)	155	110	110
Specific gravity	2.50	1.76	1.76
Maximum lump size inches (millimeters)	-4 (-100)	-6 (-150)	-6 (-150)
Rated capacity (metric tons per hour)	2,000	2,200	1,814
Operating time (hours per year)	5,000	5,000	5,000
Annual tonnage (metric tons)	10,000,000	10,000,000	4,500,000
Belt width—inches (millimeters)	36 (900)	40 (1,000)	42 (1,070)
Belt speed—feet per minute (meters per second)	600 (1.8)	900 (4.5)	824 (4.2)
Capital cost data			
Investment (1982 dollars)	$25,500,000	$98,000,000	$11,200,000
CRF (20 years at 12 percent interest)	0.134	0.134	0.134
Capital cost per year	$3,420,000	$13,130,000	$1,580,000
Operations cost data			
Maintenance parts, supplies at 2 to 4 percent investment (per year)	$1,020,000	$3,920,000	$224,000
Power (kilowatts)	(-12x224) + (15x200)	51 x 378	2 x 1120
Power unit cost (per kilowatt hour)	$0.035	$0.035	$0.035
Power cost (per year)	$76,000	$3,370,000	$392,000
Labor (number of workers)	21	55	24
Labor unit cost (per year)	$15,000	$15,000	$40,000
Labor cost (per year)	$315,000	$825,000	$960,000
Operating cost (per year)	$1,411,000	$8,115,000	$1,576,000
Cost summary			
Capital (per ton mile)	$0.03	$0.02	$0.05
Operating (per ton mile)	$0.02	$0.01	$0.05
Total (per ton mile)	$0.05	$0.03	$0.10
Unit investment (per mile)	$2,680,000	$1,580,000	$1,820,000
Total ton—miles per year	104,500,000	682,000,000	30,800,000
Total length—miles (kilometers)	9.5 (15.37)	62 (100)	6.16 (9.91)

Table 4. Unit cost for overland haulage conveyors (per ton-mile)

Conveyor	Hierro Peru	Bucraa	Twin Buttes
Capital cost	$0.03	$0.02	$0.05
Operating cost	0.02	0.01	0.05
Total	0.05	0.03	0.10

The above conveyors, as many others working today, were designed to provide many years of continuous operation at peak performance. Planning included a provision for sufficient stockpiles to feed the system and adequate storage capacity at the discharge end. In this manner, maximum continuous throughput has been the rule rather than the exception. The Hierro Peru conveyors replaced an existing truck haulage fleet. Both the Bucraa and Twin Buttes conveyors were initially selected over more expensive truck and rail haulage after careful engineering economic studies. Some highlights of the above cost analysis are:

- Lowest overall cost is attained by the longest Bucraa conveyor
- Operating costs are substantially reduced by power generation of the downhill Hierro Peru conveyors
- The smaller yearly capacity of the Twin Buttes conveyor explains its higher relative cost than that of Hierro Peru and Bucraa.

It should be noted that the above costs do not include feed preparation, such as crushing, or feed or discharge stockpile facilities.

The following assumptions have been made for the economic analysis:

- Inflation factors have been applied to obtain a capital or initial investment in 1982 dollars
- A conservatively estimated common economic life is considered to be 20 years
- Capital cost will be amortized during the 20-year life of the facility at 12 percent annual interest. The capital recovery factor (CRF) is used to obtain the capital cost per year
- The operating cost is assumed to be in constant 1982 dollars, with the following components: (a) costs of maintenance parts and supplies for belting, idlers, motors, reducers, couplings, brakes, electrical and steel, is at 2 to 4 percent of the capital investment; (b) cost of power is the installed electrical kilowatts multiplied by the unit power price and operating hours per year; (c) cost of labor is the

number of assigned operating and maintenance personnel multiplied by the yearly cost of wages, salaries, and fringe benefits per person.

B. Medium Distance Conveyors

Recently published engineering economy studies[5,6,7,8] provided the basic data to make a comparative analysis of conveyor versus truck haulage in open pit mines. Ton and ton-mile costs indicated in Tables 5 and 6 may vary substantially. Thus, the intent of this analysis is to suggest the methodology to follow.

The comparative economic analysis shows that in 1982 a belt system will cost $0.13 per ton-mile against $0.20 per ton-mile for truck haulage. The comparison of cost per ton provides a larger discrepancy: $0.26 per ton for the conveyor versus $0.38 per ton for the trucks, because conveyor routes are shorter than roads.

Table 5 shows the basic technical parameters. In Table 6, the technical data are combined with capital and operating cost information. The following assumptions have been made:

- The initial investment will be amortized during the life of the equipment, 20 years for the conveyor and 10 years for trucks, without salvage value
- The capital cost per year is the initial investment multiplied by the capital recovery factor (CRF), which uses compound interest rates in similar fashion as when making house amortization payments. This is equivalent to the Discounted Cash Flow (DCF) analysis, widely accepted in the industry.
- Operating costs are assumed as average for these type trucks.

The investment for the belt conveyor system includes the in-pit ore and waste crushers, and the waste stackers with shiftable conveyor. Also included is the cost of in-pit trucks required for carrying ore and waste to the in-pit crushers, although mines contemplating a changeover to conveyor haulage could use their old truck fleet at zero sunk cost to reduce the initial investment.

Table 5. Comparison of belt versus truck haulage: technical data

Description	Belt System			Truck Haul		
Material	**Ore**		**Waste**	**Ore**		**Waste**
Material density (pounds per cubic foot)		110				110
Specific gravity		1.76				1.76
Maximum lump size - inches (millimeters)		-8(-200)			-30(-750)	
Length (feet)	16,500		7,100	6,500		12,000
(meters)	5,000		2,200	2,000		3,660
Lift (feet)	540		440	400		700
(meters)	160		130	122		213
Number of flights	6		4	—		—
Annual capacity: (million metric tons per year)	25		49	25		49
Operating hours per year	6,000		4,500/ Truck			
Belt width (inches)	60		72		—	
(millimeters)	1,500		1,800		—	
Belt speed-feet per minute		810(4.1)			—	
Truck payload (meters per second)		100			100	
Truck cycle (minutes)		5		12		18
Tons per hour per truck		1200		500		333
Tons per year per truck		5,400,000		2,250,000		1,500,000
Fleet size		15		12 units		36 units

Table 6. Comparison of belt versus truck haulage: economics

Capital cost data	Belt system	Truck haul
Truck fleet, 15 and 48 trucks	$10,500,000	$33,600,000
Investment, conveyor system	$51,000,000	—
Haul road, 2.5 miles	—	$5,000,000
CRF (20 years, 12 percent interest)	0.134	0.134
CRF (10 years, 12 percent interest)	0.177	0.177
Truck capital cost, 10 years	$1,850,000	$5,940,000
Road capital cost, 20 years	—	$ 670,000
Conveyor capital cost, 20 years (per year)	$6,830,000	—
Total capital cost (per year)	$8,680,000	$6,610,000
Operating cost data		
Maintenance, parts, supplies at 2 & 15 percent investment (per year)	$1,020,000	$5,040,000
Installed Power (kilowatts)	15,000	—
Power unit cost (per kilowatt hour)	$0.06	—
Conveyor labor	34 men	—
Labor cost @ $40,000 per year	$1,360,000	—
Road maintenance @ 100 percent capital	—	$670,000
Hourly cost:		
Fuel @ $1 per gallon (per hour)	$30	$30
Lube @ 30 percent fuel (per hour)	$9	$9
Tire, 2,000 hours life (per hour)	$30	$30
Labor (per hour)	$20	$20
Total hourly cost	$89	$89
Fuel, lube, tire & labor cost @ 4,500 hours per year 15 & 48 trucks (per year)	$6,000,000	$19,220,000
Total operating cost (per year)	$12,420,000	$24,930,000

Cost Summary

Material	Ore		Waste	Ore		Waste
Miles	3.12		1.34	1.23		2.27
Million ton-miles per year	87.36		72.36	34.44		122.58
Million ton-miles per year		159.72			157.02	
Million tons per year		82			82	
Capital cost (per ton-mile)		$0.05			$0.04	
Operating cost (per ton-mile)		$0.08			$0.16	
Total cost (per ton-mile)		$0.13			$0.20	

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Year	Gold	Silver	Copper	Lead	Zinc	Uranium	Bauxite	Iron Ore	Tin	Molybdenum	Mercury	Nickel	Manganese Ore	Asbestos	Phosphate Rock	Potash	Sulphur	Pyrite
UNITED STATES																		
1977	1,100,347	38,165,703	1,503,906	537,499	448,685	14,600	2,218,954	55,750,000	100	122,408,000	28,244	12,958	—	93,000	51,920,000	2,229,000	11,824,486	500,000
1978	965,084	39,400,000	1,358,000	529,661	302,669	15,000	1,869,280	80,700,000	110	132,000,482	24,163	13,509	—	93,000	47,256,000	2,268,000	12,521,600	450,000
1979	970,000	31,326,797	1,444,000	551,000	294,693	18,730	1,849,904	85,700,000	110	143,967,000	29,519	15,065	—	93,000	51,611,000	2,464,000	12,846,400	440,000
1980	951,348	37,560,299	1,448,428	604,432	368,848	21,850	1,583,746	69,600,000	110	150,686,000	30,657	14,653	—	80,000	59,840,000	2,239,000	13,259,968	350,000
1981	1,303,730	29,600,000	1,292,793	488,482	335,800	19,140	1,509,587	74,307,000	110	137,303,000	27,933	15,600	—	81,000	58,190,000	2,150,000	12,985,280	300,000
CANADA																		
1977	1,757,835	42,824,500	834,500	309,051	1,177,567	7,507	—	53,621,096	361	38,448,621	N.A.	255,763	—	1,517,360	—	5,764,181	5,207,028	24,119
1978	1,735,039	40,701,900	723,273	352,000	1,173,700	9,032	—	42,931,000	396	30,674,600	N.A.	140,800	—	1,564,200	—	6,978,400	6,327,000	9,000
1979	1,644,227	36,873,092	700,020	341,820	1,209,918	7,183	—	58,552,688	369	24,584,089	N.A.	139,129	—	1,641,991	—	7,781,827	6,945,558	34,135
1980	1,552,233	33,339,550	779,257	301,216	984,032	7,004	—	49,957,675	290	26,835,600	N.A.	214,442	—	1,468,500	—	8,285,200	8,143,300	35,200
1981	1,746,031	42,433,862	791,326	300,766	1,094,553	8,538	—	53,953,010	273	31,159,611	N.A.	171,048	—	1,268,960	—	7,496,500	9,152,000	12,100
REPUBLIC OF SOUTH AFRICA																		
1977	22,501,367	3,130,253	225,500	—	152,900	4,261	—	25,951,380	3,300	—	—	24,000	5,819,000	418,000	16,041,300	—	—	913,000
1978	24,854,019	3,406,602	226,320	—	143,350	4,984	—	26,626,724	3,176	—	—	N.A.	4,597,995	283,058	20,690,611	—	—	841,643
1979	22,616,656	3,236,347	155,046	—	118,620	6,212	—	27,497,549	2,966	—	—	N.A.	5,700,577	274,106	21,225,950	—	—	350,628
1980	21,669,100	3,116,942	219,867	—	90,000	6,146	—	22,911,987	3,205	—	—	N.A.	6,281,923	295,500	21,489,378	—	—	N.A.
1981	23,139,744	8,303,252	199,424	—	95,500	7,294	—	28,318,856	2,811	—	—	N.A.	5,039,687	235,943	19,483,679	—	—	N.A.
AUSTRALIA																		
1977	624,257	27,523,936	243,737	475,424	540,769	129	28,694,600	94,004,540	11,697	—	—	94,455	1,527,900	N.A.	494,594	—	489,517**	N.A.
1978	647,565	26,122,646	244,322	440,320	520,622	187	26,721,762	81,388,218	13,050	—	—	90,594	1,382,979	N.A.	273,160	—	462,193**	N.A.
1979	588,184	26,815,061	258,208	459,233	584,946	256	30,343,500	91,709,000	12,653	—	—	80,655	1,832,600	N.A.	8,312	—	420,483**	N.A.
1980	556,838	24,746,915	238,825	437,668	543,103	568	29,895,800	95,542,000	11,661	—	—	76,835	2,157,100	N.A.	7,283	—	387,083**	N.A.
1981	618,059	25,505,288	245,687	432,424	554,631	568	28,095,100	93,259,100	13,291	—	—	81,409	2,559,800	N.A.	5,430	—	392,116**	N.A.
MEXICO																		
1977	212,733	47,035,305	98,628	179,827	292,016	—	—	3,523,003	128	2,000	9,657	37	192,702	—	—	—	2,041,782	—
1978	201,999	50,777,484	95,905	187,586	269,381	—	—	3,492,455	344	24,000	8,178	24	207,174	—	—	—	1,999,454	—
1979	190,039	49,407,219	117,820	190,801	270,025	—	—	3,968,655	220	105,000	—	22	195,095	—	—	—	2,227,979	—
1980	195,986	47,342,707	175,399	145,549	238,231	—	—	5,087,361	220	130,000	—	20	177,062	—	—	—	2,102,301	
1981	185,000*	51,654,829	230,466	157,384	211,629	—	—	5,292,609	70*	150,000*	150,000	—	N.A.	208,193	—	—	—	2,077,117
CHILE																		
1977	105,000	7,600,000	1,115,859	1,650	4,950	—	—	7,535,000	—	24,118,290	—	—	12,100	—	—	20,000	10,000	N.A.
1978	99,998	8,282,000	1,134,912	475	1,994	—	—	7,666,151	—	28,828,800	—	—	25,567	—	—	20,000	10,000	N.A.
1979	104,100	8,625,000	1,167,100	660*	2,200*	—	—	7,451,535	—	29,829,800	—	—	26,400*	—	—	N.A.	N.A.	N.A.
1980	114,800	10,120,000	1,179,400	660*	1,650*	—	—	8,800,000	—	30,124,272	—	—	26,400*	—	—	N.A.	N.A.	N.A.
1981	297,000	10,200,000	1,080,310	299*	1,097*	—	—	7,648,500	—	33,853,440	—	—	24,000*	—	—	N.A.	N.A.	N.A.
PERU																		
1977	80,000	30,100,000	415,250	190,300	518,000	—	—	6,093,000	—	1,040,000	—	—	—	—	—	—	—	—
1978	78,000	39,000,000	424,050	187,550	518,000	—	—	4,843,700	—	1,694,000	—	—	—	—	—	—	—	—
1979	141,700	43,415,000	400,387	202,708	622,930	—	—	5,358,158	—	3,931,400	—	—	—	—	—	—	—	—
1980	148,900	39,609,700	363,600	192,912	542,300	—	—	5,600,000	—	4,848,800	—	—	—	—	—	—	—	—
1981	220,000	46,878,000	327,600	205,370	546,370	—	—	4,033,700	—	6,012,512	—	—	—	—	—	—	—	—
POLAND																		
1977	—	—	338,000	93,940	250,800	—	—	—	—	—	—	—	—	—	—	—	5,241,500	—
1978	—	—	337,700	370,940	244,200	—	—	—	—	—	—	—	—	—	—	—	5,556,100	—
1979	—	—	396,600	92,620	229,900	—	—	—	—	—	—	—	—	—	—	—	5,313,000	—
1980	—	—	392,700	90,200	236,500	—	—	—	—	—	—	—	—	—	—	—	5,703,500	—
1981	—	—	340,000	N.A.	N.A.	—	—	—	—	—	—	—	—	—	—	—	N.A.	—
PHILIPPINES																		
1977	559,959	1,570,014	293,759	4,128	13,989	—	—	—	—	28,652	—	40,333	22,954	—	—	—	—	—
1978	616,702	1,687,240	300,603	1,866	10,263	—	—	1,922	—	121,220	—	34,151	3,912	—	—	—	—	—
1979	530,684	1,804,226	326,740	2,145	10,641	—	—	3,253	—	260,072	—	31,638	5,497	—	—	—	—	—
1980	654,405	1,920,046	305,687	1,782	7,777	—	—	—	—	193,592	—	25,382	—	—	—	—	—	—
1981	752,561	1,969,654	300,650	1,015	5,233	—	—	—	—	176,320	—	21,456	—	—	—	—	—	—
JAPAN																		
1977	148,899	9,637,886	89,529	60,240	303,304	—	—	614,900	664	272,662	—	—	138,772	—	—	—	N.A.	1,411,943
1978	146,864	9,740,949	80,724	62,553	302,589	—	—	581,900	603	195,360	—	—	118,236	—	—	—	N.A.	1,232,613
1979	132,876	8,665,068	59,960	51,621	267,689	—	—	458,000	726	182,160	—	—	97,173	—	—	—	N.A.	948,584
1980	145,222	8,878,705	58,540	49,241	261,940	—	—	478,000	604	143,880	—	—	87,536	—	—	—	N.A.	802,490
1981	99,300	8,981,700	56,700	51,740	266,800	—	—	478,000	577	260,000	—	—	N.A.	—	—	—	N.A.	N.A.

YUGOSLAVIA																		
1977	180,200	4,693,900	133,265	142,879	108,726	—	2,284,700	4,361,980	—	—	3,132	—	27,225	9,973	—	—	—	541,200
1978	223,000	5,131,140	165,911	128,373	101,455	—	2,822,600	4,472,720	—	—	928	—	34,914	11,396	—	—	—	470,800
1979	N.A.	5,208,300	151,250	122,144	108,247	—	3,313,200	4,534,356	—	—	—	—	35,552	11,045	—	—	—	N.A.
1980	N.A.	4,790,350	144,417	111,926	92,990	—	3,451,800	4,449,094	—	—	N.A.	—	40,040	13,317	—	—	—	N.A.
1981	614,473	4,871,339	111,700	130,000	106,000	—	3,249,000	N.A.	—	—	N.A.	—	33,400	13,591	—	—	—	N.A.
BOLIVIA																		
1977[7]	18,948	5,953,981	4,037	20,285	66,843	—	—	—	35,878	—	—	—	—	—	—	—	N.A.	—
1978	24,755	6,462,305	3,593	14,758	63,481	—	—	—	33,878	—	—	—	—	—	—	—	N.A.	—
1979	30,300*	5,556,665	1,941	17,029	56,524	—	—	—	30,672	—	—	—	—	—	—	—	N.A.	—
1980	52,074	6,099,337	2,071	18,946	55,286	—	—	—	29,998	—	—	—	—	—	—	—	N.A.	—
1981	66,771	6,601,568	2,637	16,756	47,028	—	—	—	29,780	—	—	—	—	—	—	—	N.A.	—
BRAZIL																		
1977	190,000	—	441	—	44,080	—	1,157,100	73,795,705	10,469	—	—	6,171	896,000	105,000	540,000	—	34,000	—
1978	210,000	—	441	—	52,800	—	1,250,000	74,250,000	10,200	—	—	6,600	876,960	110,000	560,000	—	34,000	—
1979	143,389	—	5,780	—	69,843	—	3,172,120	117,502,000	11,691	—	—	3,260	2,145,881	110,000*	581,250	—	35,000*	—
1980	482,178	—	11,000	—	84,700	—	3,300,000	111,800,000	11,702	—	—	2,795	1,353,176	110,000*	930,000	—	35,000*	—
1981	514,488	—	17,960	—	67,120	—	3,569,000	108,800,000	14,000	—	—	2,992	2,100,000*	110,000*	2,800,000	—	35,000*	—
SWEDEN																		
1977	67,900	5,098,990	45,540	88,660	152,460	N.A.	—	24,907,680	—	—	—	—	—	—	—	—	13,000	442,200
1978	76,300	5,144,000	49,841	83,655	181,500	N.A.	—	21,056,280	—	—	—	—	—	—	—	—	15,000*	532,400
1979	70,000	5,700,000	52,800	79,695	173,316	N.A.	—	26,060,000	—	—	—	—	—	—	—	—	N.A.	492,800
1980[1]	70,000	5,700,000	49,775	67,320	178,398	N.A.	—	26,698,569	—	—	—	—	—	—	—	—	N.A.	435,600
1981[1]	70,000	5,400,000	51,000	81,180	194,722	N.A.	—	25,547,000	—	—	—	—	—	—	—	—	N.A.	463,100
ZAIRE																		
1977	103,000	2,730,000	530,000	—	80,000	—	—	—	3,916	—	—	—	150,000	—	—	—	—	—
1978	80,000*	2,716,000*	463,100*	—	91,850*	—	—	—	2,549*	—	—	—	—	—	—	—	—	—
1979	96,000*	2,850,000*	446,600*	—	80,500*	—	—	—	2,200*	—	—	—	—	—	—	—	—	—
1980	80,375*	2,777,040	495,000*	—	73,000*	—	—	—	2,860	—	—	—	—	—	—	—	—	—
1981	70,000*	2,500,000*	500,000*	—*	83,800*	—	—	—	2,500*	—	—	—	—	—	—	—	—	—
ZAMBIA																		
1977	9,967	964,500	715,000	17,600	44,000	—	—	—	—	—	—	—	—	—	—	—	N.A.	22,551
1978	8,326	1,069,341	659,602	13,971	46,742	—	—	—	5	—	—	—	—	—	—	—	1,002	22,000*
1979	7,973	913,606	644,651	14,033	42,034	—	—	4,161	2	—	—	—	—	—	—	—	1,358	N.A.
1980	10,288*	761,955*	670,929	11,000	24,970	—	—	4,550	—	—	—	—	—	—	—	—	1,500	N.A.
1981	11,500*	714,400*	600,000	17,000*	36,799*	—	—	N.A.	—	—	—	—	—	—	—	—	N.A.	N.A.
SOUTH WEST AFRICA[8]																		
1977	—	N.A.	44,000	49,500	24,200	2,750	—	—	605	—	—	—	—	—	—	—	—	N.A.
1978	—	N.A.	49,500	44,000	24,200	4,400	—	—	842	—	—	—	—	—	—	—	—	N.A.
1979	—	N.A.	42,900	38,500	22,000	5,478	—	—	770	—	—	—	—	—	—	—	—	N.A.
1980	—	N.A.	44,561	55,000	26,401	5,775	—	—	770	—	—	—	—	—	—	—	—	N.A.
1981	—	N.A.	45,000*	55,000*	26,000*	5,775*	—	—	770*	—	—	—	—	—	—	—	—	N.A.
FRANCE																		
1977	41,795	6,976,550	—	34,629	46,011	2,307	2,264,680	35,903,280	—	—	—	—	—	—	—	1,727,000	2,178,000	—
1978	41,795	6,526,450	—	31,195	45,206	2,105	2,175,250	32,784,920	—	—	—	—	—	—	—	1,958,000	2,090,000	—
1979	40,445	7,355,480	—	28,529	39,670	2,596	2,167,000	31,100,160	—	—	—	—	—	—	—	2,113,000	2,135,100	—
1980	35,365	7,652,288	—	28,459	38,766	2,860	2,081,761	29,000,000	—	—	—	—	—	—	—	2,080,177	2,024,000	—
1981	32,205	9,728,000	—	29,275	39,318	2,555	2,081,761	21,800,000	—	—	—	—	—	—	—	1,831,000	2,024,000	—
NORWAY																		
1977	—	—	31,625	3,604	34,320	—	—	3,724,000	—	—	—	568	—	—	—	—	—	181,500
1978	—	—	31,818	3,604	32,375	—	—	3,586,000	—	—	—	561	—	—	—	—	—	161,315
1979	—	—	31,585	3,296	31,172	—	—	2,614,238	—	—	—	652	—	—	—	—	—	132,304
1980	—	—	32,311	2,985	30,840	—	—	2,447,644	—	—	—	531	—	—	—	—	—	208,285
1981[1]	—	—	28,665	3,214	29,696	—	—	2,612,830	—	—	—	4,000	—	—	—	—	—	206,300
FINLAND																		
1977	27,392	812,881	51,017,	1,533	96,711	—	—	2,728,418	—	—	630	6,206	—	—	—	—	37,000	385,013
1978	31,928	1,243,443	52,398	1,870	121,822	—	—	1,877,258	—	—	1,145	4,677	—	—	—	—	35,000*	251,900
1979	26,000	1,028,000	46,769*	1,928*	63,880	—	—	773,900*	—	—	1,340*	3,500*	—	—	—	—	N.A.	180,196
1980	41,800	1,000,000	38,551*	1,779*	67,997	—	—	810,000*	—	—	2,155*	4,020*	—	—	—	—	N.A.	182,957
1981	40,000	900,000	42,100*	1,800*	59,100	—	—	810,000*	—	—	2,155*	4,020*	—	—	—	—	N.A.	268,882

1. Preliminary. 2. Ounces. 3. Short tons. 4. Long tons. 5. Pounds. 6. Flasks. 7. Exports. 8. No official statistics released for South West African mineral production. The figures given here are compiled by WORLD MINING editors from a variety of individual sources. *Estimated.
**Includes Sulphur content of pyrite. N.A. Not available.

ALGERIA

Recent exploration has resulted in the discovery of mercury, barite, and kaolin in the north of the country. In the south, gold has been discovered at Tiririne, uranium at Timgaouine-Abankor, tungsten at Laouni-Bachir, and iron ore at Abdeaaziz Mechri. The current five-year plan calls for an investment of some $600,000,000 in the mining industry.

The Ain Mimoun barite mine, 26 kilometers (16 miles) from Oum El Boughi, is the biggest of the four Algerian barite mines. It is currently producing some 48,000 metric tons per year from open pit and underground sections.

ANGOLA

Austromineral submitted a report in early 1981 in which it concluded that there were 21,700,000 metric tons of proven, recoverable detrital iron ore in the former mining areas of Kassinga North, in Huila province southern Angola, all amenable to economical surface mining. The Kassinga South ore is not to be developed at the present time. Proven recoverable reserves at this deposit are estimated to be 12,500,000 tons. The Kassinga iron ore districts are some 520 kilometers (320 miles) east of the coastal port of Moçâmedes, to which they are connected by a narrow-gauge railroad.

The run-of-mine ore from Kassinga North contains about 44 percent Fe. The modified processing plant at Jamba has a throughput capacity of approximately 2,000,000 tons of ore per year, from which some 1,100,000 tons of hematite concentrate assaying 62 to 63 percent Fe will be produced. It will be shipped to Moçâmedes for export. Regular production of sinter-feed and lump ore will start in mid-1983.

La Compagnie de Diamants de l'Angola (Diamang) is reported to be making significant progress in revitalizing the important diamond mining industry. In 1980 production rose to over 1,000,000 carats, compared with 840,000 carats in 1979. Production in the past has been as high as 2,400,000 carats per year. The state company Endiama has now taken over all prospecting, mining, and marketing of Angolan diamonds.

A phosphate mine at Kondonakasi, in the north of the country, is being developed in a joint venture with Bulgaria. It is reported that the mine is expected to be in operation this year and that there are estimated reserves of 200,000,000 tons.

BENIN

Benin's mineral resuorces remain largely unexplored. The limited amount of prospecting that has been been carried out, without much coordination, has produced results that offer some prospects for the future. Phosphate deposits have been discovered in the north with an average P_2O_5 content ranging from 20 to 32 percent. Definitely proven reserves amount to 2,500,000 metric tons, while probable reserves are estimated at between 5,000,000 and 6,000,000 tons. This would be sufficient to meet domestic agricultural demand with some for export. Iron ore reserves, also in the north, have been estimated at some 500,000,000 tons of average iron content. Again, these would meet domestic demand, with some extra for export.

Gold exploration has been relatively intensive, concentrated on deposits at present limited in extent, but with seams of 80 grams (2.6 ounces) per ton. Indications of other minerals such as rutile, chromite, uranium, zinc, lead, and nickel have been found which, though not very encouraging judging from the little exploration carried out, may offer future potential with further investigation.

Kaolin deposits are reported to exceed local demand. Exploration of the Arlan limestone deposits, which run from east to west across the country, has already resulted in the development of mining operations. The limestone is processed for the Onigbolo cement works, which has an annual capacity of 500,000 tons. There are also indications of greater potential, in quality and quantity, in the Masse region and in Mono. These two deposits could be developed to supply the two clinker plants in the south.

Medium-term programs for the development of mineral resources will focus on phosphates; kaolin; marble, through a joint venture company formed with Libya (Belimine) to develop deposits in Zou province; iron ore; and the Perma (Atakora) gold prospects. In the next three to five years, the completion of geological mapping and exploration programs at clearly indentified targets will allow a more systematic program for developing and upgrading Benin's mineral potential to be drawn up.

BOTSWANA

The government has become guarantor of the financially troubled BCL Ltd., which operates the nickel/copper mines at Selebi Pikwe. The company has a history of financial problems, which are now deepening with the recession, despite the fact that production in 1981 attained a new record level. A total of 46,565 metric tons of matte were produced, compared with the previous record, in 1980, of 40,099 tons. Metal contained in matte sales, before refining, amounted to 17,634 tons of nickel, 17,333 tons of copper, and 253 tons of cobalt.

The total ore milled was 2,460,000 tons producing 687,000 tons of concentrate, the highest annual figure to date. Mill head grades were lower than planned at 0.89 percent Ni and 0.81 percent Cu. The year was the first full year of production from the Selebi mine, which produced 830,000 tons, more than was planned, containing 0.52 percent Ni and 0.91 percent Cu. Late in the year shipments of low sulphur matte to Rio Tinto Mining (Zimbabwe) Ltd. began.

The exploration drilling program continued to produce positive results in all areas, with an 80 percent success rate from 35 holes completed. Current estimates have placed the total reserves at 39,888,000 tons comprising: proven reserves of 23,910,000 tons at Phikwe and Selebi; probable reserves of 13,978,000 tons at Phikwe, Selebi, and Selebi North; and total inferred reserves at all three of 22,000,000 tons. The grades of the 37,888,000 tons of proven and probable reserves are 0.96 percent Ni and 1.05 percent Cu.

Botswana, through De Beers Botswana Mining Company (Pty) Ltd. (Debswana), produces 15 percent of the world's diamonds. Production in 1981 was 9,630,400 tons of ore, from which 4,960,252 carats were recovered. Over 90 percent of the diamond production came from the Orapa mine, the remainder from Letlhakane.

Development of the Jwaneng project continued on target. During the year, 4,445,695 bank cubic meters of waste and overburden were stripped and 1,467,050 bank cubic meters of ore were mined. Construction of the main treatment plant was almost complete by the end of the year. The plant went into the production build-up phase in January 1982 and was on target to reach its planned throughput of 400,000 tons per month. At full capacity, Jwaneng is expected to produce 3,500,000 carats per year.

Evaluation of Kimberlite 2424 DK2 at Letlhakane continued with the drilling of 380-millimeter diameter holes on a 50-meter grid and the sinking of vertical shafts with horizontal development. Drilling in the northeast lobe is expected to be completed in October 1982, ending the final stage of the initial evaluation program.

BURUNDI

Geological surveys have indicated that Burundi's Buhinda Plateau offers good prospects for nickel and other minerals, such as copper, cobalt, and platinum. The International Development Association last year approved a credit of $4,000,000 to explore these potential resources.

The nickel laterites in the Musongato area are likely to be developed in the near future. One report estimates the reserves to be 73,000,000 metric tons of ore at grades of 1.6 percent Ni, 0.3 percent Cu, and 0.1 percent Co. Immediately surrounding this area, there are thought to be further reserves of some 300,000,000 tons. UOP Inc. has already carried out full-scale pilot plant tests on the ore and reports that the nickel, copper, and cobalt can all be satisfactorily recovered using a new process.

The British Sulphur Corporation Ltd. is undertaking a feasibility study to determine the prospects of establishing phosphate fertilizer production facilities, based on the phosphate deposits of Matongo-Bandaga. The study will prove the reserves and investigate the production of phosphatic and compound fertilizers, together with cement from the carbonatite deposit. It is envisaged that while cement production will primarily meet domestic demand, the phosphatic fertilizers could be produced for the home market and for export to neighboring countries.

CAMEROON

A new company is carrying out a prefeasibility study of the Kribi iron ore deposit. The extent of the reserves has not yet been accurately assessed, but initial work indicates 200,000,000 metric tons at an average grade of 30 percent Fe, with no impurities. The company, Société d'Etudes de Fer du Cameroon (Sefercam), is also considering the establishment of an integrated steel complex at Kribi.

There are many mineral projects outlined in the fifth national plan. In the southeast, covering an area of 65,000 square kilometers (25,100 square miles), preliminary work resulted in the discovery of indications of uranium, diamonds, iron ore, copper, nickel, and chrome. Further work will involve the economic evaluation of these prospects. Work in the southwest, covering an area of 70,000 square kilometers (27,000 square miles), will consider the feasibility of mining the iron, rutile, rare earths, and nepheline syenite prospects that have already been discovered.

The bauxite reserves of Adamaoua are high grade, containing 43 percent alumina, and estimated to contain 800,000,000 tons. Sebacam, having conducted a study that suggested the feasibility of mining the deposit, is continuing with further research. Similarly, in the west there are major bauxite reserves of some 80,000,000 tons of good quality ore. The deposits are distributed around Fongo-Tongo, Dschang, Foumban, and Bangam. Current studies are aimed at verifying the feasibility of setting up an integrated complex to mine and process the bauxite.

During 1980-81 Alucam produced 52,236 tons of aluminum. An expansion project, which was completed in June last year, has now increased the capacity of the Edéa aluminum smelter from 50,000 to 84,000 tons per year.

Gold deposits in the east have been extensively explored and will eventually be developed. Similarly, rutile deposits in the regions of Edéa and Nanga-Eboko are to be developed after further studies.

CONGO

The search for radioactive ore in the north of the country and in Mayombe was increased and intensified. The Société Agip Uranium, which was granted the Niari permit in 1979, continued uranium exploration in Mayombe. It was centered in the Mayombe and Bouenza zones. The official report on the work has not yet been published. The emphasis of the previous reports indicate negative drilling results.

At the same time, in the north of the country, SNEA, which has been granted an exploration permit, carried out a geological survey. It is too early at the moment to conclude the outcome of events.

The five-year plan (1982-86) is the only hope of inensifying mineral research. A good number of projects were delayed, particularly in the northwest.

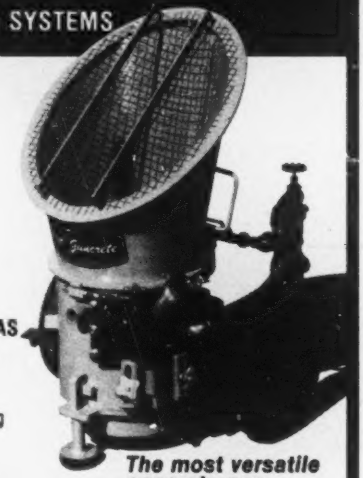
Gold mining has been in recession for a number of years. In 1981 only 1.5 kilograms were produced, compared with 19 kilograms in 1980 and 148 kilograms in 1968. In contrast, lead concentrate was slightly up, and reached a peak of 15,000 tons, compared to 5,229 tons in 1980.

Undersea phosphate exploration was carried out off the Atlantic coast. Negotiations are underway to restart potash mining in the Kouilou region.

The F. A. C. is financing a project to study the iron ore reserves of Mounts Nabeba and Auima, in the north.

EGYPT

The construction of a new concentrator on the Red Sea coast to treat ore from cassiterite placer deposits is proceeding.



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Egyptian mineral production in metric tons

Commodity	1979	1980	1981
Iron ore	1,436,000	1,869,700	1,943,500
Phosphate	643,000	702,500	736,800
Barite	8,701	8,800	2,108
Bentonite	5,000	5,200	3,700
Clays	950,000	810,000	995,000
Feldspar	3,300	4,400	3,500
Fluorspar	700	770	550
Kaolin	40,000	49,000	32,200
Limestone	5,900,000	6,200,000	5,534,800
Quartz	8,800	9,900	12,830
Talc	5,500	5,400	5,800
Asbestos and vermiculite	600	1,040	1,600
Marble[1]	26,000	33,000	46,900

1. Cubic meters. 1.0 metric ton = 1.1 short tons. 1.0 short ton = 0.907 metric ton.

All the equipment was imported from the United States.

Detailed investigations to evaluate the gold deposits of the central Eastern Desert were almost finished. The next step will be a feasibility study.

The problems facing benefication of the phosphate deposits at Abu Tartur in the Western Desert have not been solved yet. The production of phosphate ore from the other mines is still below targeted levels. A comprehensive plan for sulphur exploration was established in 1981 in cooperation with the United States; the program is expected to start next year.

A new geological map of Egypt was published in 1981. This is only the third this century. The other two were published in 1927 and 1971.

EQUATORIAL GUINEA

New mining laws announced during 1981 permit foreign companies to participate in exploration, development, and mining. The laws cover industrial, radioactive, and non-radioactive minerals. The duration of permits granted to overseas companies is limited to 25 years, and the total lease area to 150,000 hectares (370,370 acres).

Companies will have to relinquish 75 percent of the permit area after 15 years. Taxes and other charges will be at a rate of 20 percent until development costs are recouped, and 50 percent thereafter. Royalties will be based on teh size of the concession, increasing with the duration of the holding.

Equatorial Guinea has never had a commercial mining industry, neither on the island of Bioko (formerly Fernando Po), nor on the mainland province of Rio Muni. Recent Spanish exploration work has revealed some gold-silver deposits in Rio Muni.

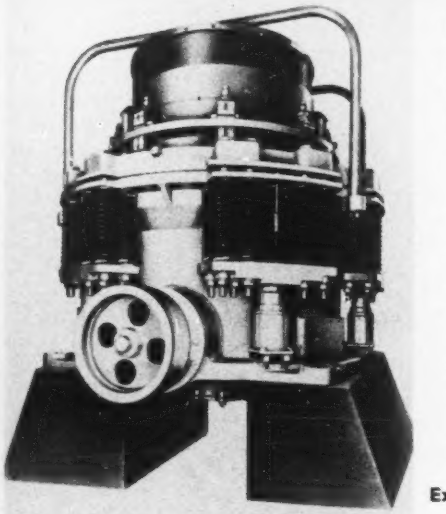
Additionally, the country's immediate neighbors give some reason for optimism; Cameroon has commercial deposits of bauxite and iron ore, while Gabon has manganese, iron ore, and uranium.

GABON

The major development of 1981 was a 30-percent decrease in the export of manganese. Production fell to 1,481,538 metric tons compared with 2,163,380 tons in 1980. The decline in production was caused by the liquidation of stocks by ferro-manganese producers with a consequent fall in demand. In addition, there was a significant decline in purchases from eastern European countries, notably Poland and Romania, hit by the economic crisis. The outlook for 1982 is uncertain.

The manganese mining company Compagnie Minière de l'Ogooué (Comilog) continued with its exploration of a copper-molybdenum anomaly near the confluence of the Nounah and Ivindo rivers in the north of the country. General prospecting work in the area has now covered 500 square kilometers (193 square miles). The mineralization consists of fine chalcopyrite, pyrite, pyrrhotite, and molybdenite. Further results are awaited.

Société des Mines de Fer de Mékambo (Somifer) is conducting a feasibility study of the rich Belinga iron ore deposits. The studies involve deposits amounting to more than 500,000,000 metric tons of ore with an iron content of 65 percent. Some 200,000,000 tons have a phosphorus content of 0.1 to 0.2 per



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cent, while the remainder contains less than 0.1 percent.

Somifer envisages the eventual mining of the iron ore deposits of Boka Boka, Belinga, and Batoula, all situated in the northeast between Mekambo and Makokou. Total reserves are 850,000,000 tons. Mining is expected to be at a rate of 5,000,000 to 7,000,000 tons per year. All the plans are dependant on the construction of the 240-kilometer (150-mile) Booué to Belinga section of the Transgabon railway. Ore will probably be shipped from the port of Owendo, just south of Libreville.

The uranium market showed little development and, taking into account sales potential, production was maintained at very much the same level as in 1980. Output was 1,360 tons of concentrate containing 1,022 tons of metal, compared with 1,381 tons of concentrate containing 1,033 tons of metal in the previous year. In contrast the sales value fell by 14 percent.

Uranium, gold, and barite were the object of exploration in 1981, of which uranium remains the primary target. A group comprising the state, Compagnie Générale des Matières Nucléaires (Cogema), and Kepco carried out 13,500 meters of drilling in an evaluation program of the Nord-Leyou section, in the Lastoursville region. The results were not very encouraging.

Cogema continued its reconnaissance of the south Franceville area. A dozen exploration holes, totalling 5,500 meters, were drilled. Comuf carried out 1,175 meters of drilling on the Lekedi and Bagombé prospects.

The Etéké consortium, involving the state, Bureau de Recherches Géologiques et Minières (BRGM), and Compagnie des Mines d'Uranium de Franceville (Comuf), continued its gold exploration in the Etéké-Ovala region. Several mineralized zones were found at Ovala and at Ndombo-Mobi. Core drilling will be carried out during 1982.

After discontinuing its lead-zinc exploration, the Kroussou syndicate concentrated its research on barite, of which numerous indications were observed along the contact of the cretaceous basement. A number of geochemical anomalies in the Mayombe massif were verified and surveys of indications noted previously were carried out. Two indications on the axis between Mayumba and Tchibanga appear interesting. They will be studied in detail in 1982.

The program of mapping, and the mineral inventory of, the zone crossed by the Transgabonais was continued in 1981. A radiometric survey of the whole territory was carried out by Aero Service Corporation of the United States. Elsewhere the Service Géologique National and BRGM prospected and surveyed an area of about 6,500 square kilometers (2,510 square miles) in the provinces of Estuaire (east Cocobeach) and Woleu-N'Tem (south Mitzic).

Plans for 1982 include a 130,000-square kilometer (50,180-square mile) aerial geophysical survey and an 8,000-square kilometer (3,088-square mile) geological survey in these regions. BRGM, Elf-Gabon, and Comilog are considering the feasibility of mining barite at Dourekiki in the Nyanga region. Reserves are estimated at 800,000 tons with a potential output of 25,000 to 35,000 tons per year.

GHANA

Despite the political upheavals, total gold production increased to 14,000 kilograms (450,100 ounces). Ashanti Goldfields Corporation and the State Gold Mining Corporation control three smaller underground operations and a number of dredges. All of the state operations run at a loss. Output in Ghana is scheduled to rise again in 1982, following improvements at several of the mines; it is not known whether these developments are continuing. In late 1980 the discovery of a gold deposit of major significance was announced. It was also announced that exploration would proceed during 1981, but no further information has been given.

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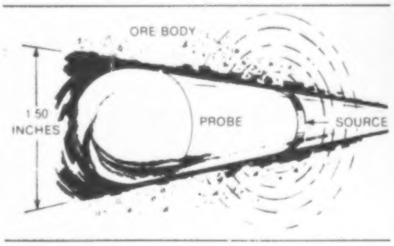

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the new regime that they will be allowed to keep 20 percent of their export earnings to pay for vitally needed spare parts and new equipment. In the case of Ashanti, the eased pressure of spares and stores should allow the production at Obuasi to be increased to between 9,020 and 9,330 kilograms (290,000 and 300,000 ounces) of gold. Production in 1981 was 7,776 kilograms (250,000 ounces), an increase of 12 percent over the 6,998 kilograms (225,000 ounces) produced in 1980. The company had received a loan of some $28,000,000 from the Union Bank of Switzerland, which refines all of Ghana's gold.

France is expected to lend more than $7,000,000 to finance the rehabilitation of Tarkwa Goldfields Ltd.'s operation in the western region. This mine is thought to have good potential for the future, perhaps the best of any of the current operating gold mines. In 1979, the last year when figures were available, 1,213 kilograms (38,400 ounces) of gold were produced. The mine was designed to produce 5,287 kilograms (170,000 ounces) per year. Lonrho had submitted a report on the Tarkwa basin that confirms its potential for massive long-term expansion of the gold mining industry.

Kibi Bauxite Development Company is planning a bauxite mine with a capacity of 2,500,000 metric tons per year and an 800,000-ton alumina refinery. The project is scheduled for completion in 1985. Reserves of the Kibi deposit, 75 kilometers (47 miles) north of Accra, are estimated to be 150,000,000 tons. A feasibility study is being conducted by a consortium led by Brown & Root Inc. Process technology is being supplied by Alusuisse-Swiss Aluminium Ltd.

The infrastructural studies will include the feasibility of building a railway from Kibi to connect with the main railway and deepening the port of Tema. There is already an aluminum smelter at Tema, operated by Volta Aluminium Company (Valco), which imports alumina from Jamaica.

Production began at Ghana's first manganese processing plant at Nsuta in the western mining district. The plant has a theoretical capacity of 480,000 tons per year.

GUINEA

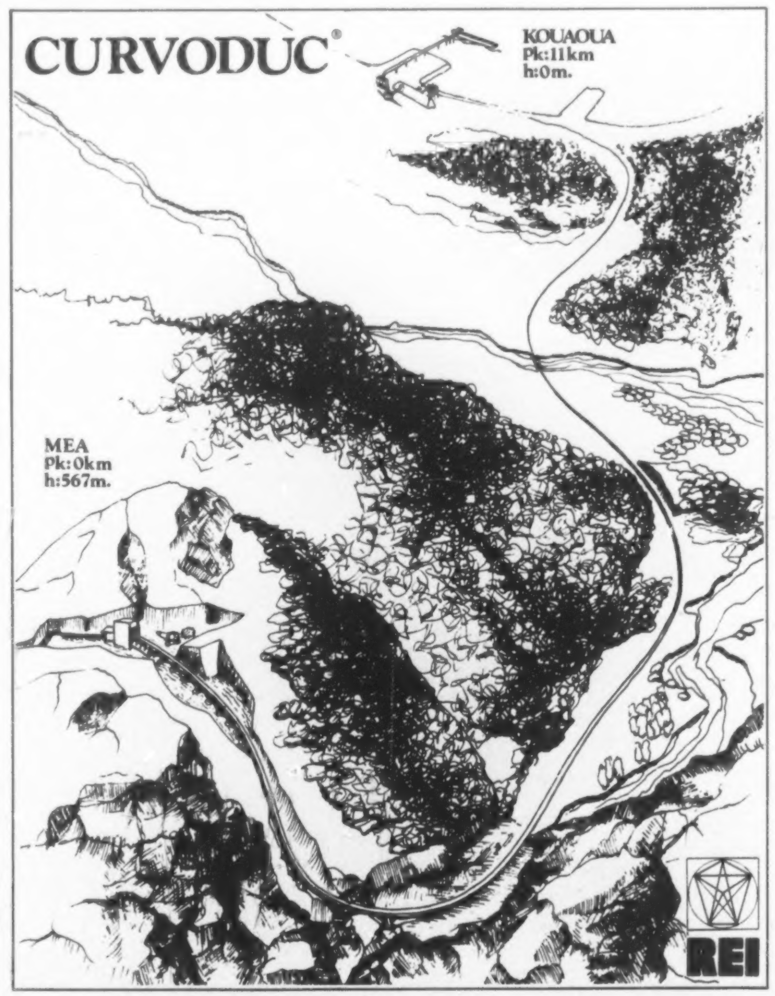
The mining sector still accounts for a little more than 20 percent of Guinea's gross domestic product and 97 percent of its exports. Bauxite is by far the most important mineral product and three mines are currently operational. The largest is the Boké mine of Compagnie des Bauxites de Guinée (Cbg), which produced 9,000,000 metric tons in 1980 and 9,500,000 tons in 1981.

Reserves of the Boké deposit are 2,000,000,000 tons containing 58 to 62 percent Al_2O_3. Output is expected to reach 10,000,000 tons in 1982.

The Kindia deposit, with reserves of 100,000,000 tons containing 48 to 52 percent Al_2O_3, is mined by l'Office des Bauxites de Kindia (Obk) at a rate of some 3,000,000 tons per year. The Fria mine, developed by Pechiney in 1960, has reserves of 500,000,000 tons containing 45 to 48 percent Al_2O_3 and currently produces at a rate of 650,000 tons per year.

Two further deposits are being developed: that of Gaoual-Aye Koye, with reserves of 1,300,000,000 tons containing 58 to 62 percent Al_2O_3; and the Dabola deposit, containing 1,000,000,000 tons at a grade of 48 to 52 percent Al_2O_3. The Aye Koye project, to the north of Sangaredi, is the most advanced. Another prospect in the northern region of Tougué is also being studied. Reserves here are estimated at 4,000,000,000 tons at a grade of 47 to 52 percent Al_2O_3.

The country's reserves of iron ore are estimated at 15,000,000,000 tons. The Mount Nimba deposit, with reserves of 2,000,000,000 tons grading 68 percent Fe, will be developed first. The company, Mifergui, aims to produce 15,000,000 tons per year of a single product suitable for sintering by about 1987. The Nimba deposit is an extension of that worked by the Lamco Joint Venture in Liberia. This has been important to the develop-



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ment of Nimba and its ore will be shipped through Liberia with only an 18-kilometer extension of the existing Lamco railroad to Buchanan necessary.

Other iron ore deposits in the country are: Mount Simandou, with reserves of 7,000,000,000 tons at 65 to 70 percent Fe; Kaloum (Conakry), 6,000,000,000 tons at 50 to 52 percent Fe; Forecariah, 100,000,000 tons at 40 to 50 percent Fe; and the Tomine basin, 500,000,000 tons at 45 to 50 percent Fe.

Four joint ventures between the government and various foreign companies are involved in diamond exploration. The prinicipal deposits are found in the region of Kerouane, Beyla, Macenta, Guekedou, and Kissidougou. Total reserves are currently estimated at some 30,000,000 carats, of which 70 percent are gem quality.

One of the joint ventures involves the Association pour la Recherche et l'Exploration de Diamant et d'Or (Aredor). This project involves a 25-year lease covering 23,000 square kilometers in a historical gold and diamond producing region in the Kissidougou Banankouru area. To date only a small part of the lease has been explored but reserves of gem quality diamonds in excess of 1,000,000 carats have been established. Kimberlite pipes exist but exploration is concentrating on alluvial deposits where mining will be developed.

Initial production is expected to be at a rate of 400,000 cubic meters per year rising to 1,000,000 cubic meters by 1985. Output is expected to be 200,000 carats in the early stage, increasing to 500,000 carats later. There are indications of gold in the area and gold recovery will be integrated with diamond mining.

Two of the other joint ventures involve Industrial Diamond Company, with a prospecting area of 30,000 square kilometers, and Charles Anthony Diamonds, with an exploration lease of 20,000 square kilometers.

Société Minière International du Quebec Inc. (Somiq) is developing an open pit gold mine in the northeast of the country. Most of the gold occurs in eluvial formations, but there are some placer deposits near river beds. The company is estimating an overall grade of 5 grams (0.16 ounce) per ton and expects working costs to be under $10 per ton. A plant processing 1,000 tons per day went into operation in early 1982. Somiq has acquired the leases to an area of 39,000 square kilometers.

Gold has been mined for many centuries. The richest known reserves are in the Dinguiraye, Kourouma, Siguiri triangle. Other deposits are reported at Curekaoa and N'Zerekore. Actual reserves are estimated at 10,000,000 tons of ore. There is potential for the development of small mines.

In the west, preliminary investigations were carried out on pyrite deposits in the regions of Kamkasta, Compory, Kuda, Kinya, and all along the river Cogon. Initial results indicate a deposit more than 50 kilometers long and averaging 8 kilometers wide. It could contain around 250,000,000 tons of ore.

Uranium is known to occur at Bomai (N'Zerekore), Kalinka (Dinguiraye), and also in the regions of Mali Siguiri, Beyla, and Yomou. Significant limestone deposits have been found at three places: Sougueta, 10,000,000 tons; Lebekere, 12,000,000 tons; and Siguiri, 15,000,000 tons.

IVORY COAST

Diamond mining in the Tortiya region ceased in 1980, and prospecting programs are now the major mining activity in the Ivory Coast. Despite the difficult economic situation, the following mining companies have continued and intensified, in 1981, their prospecting campaigns: Société pour le Développement Minier de la Cote d'Ivoire (Sodemi), Société Nationale d'Opérations Pétroliès (Petroci), Bureau de Recherche Géologique et Minière (BRGM), Compagnie des Mines et des Matériaux (Comimat S. A.) and Compagnie Minière de Cote d'Ivoire (Comici).

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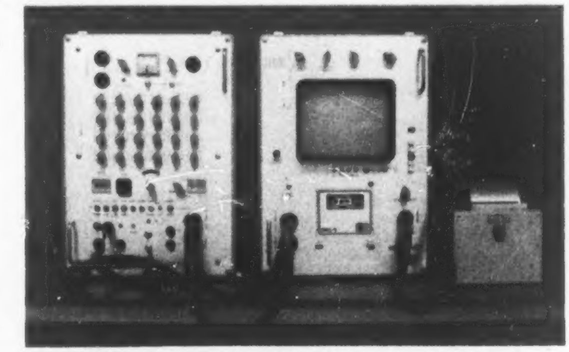

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Sodemi, in 1981, prospected for sulphide, gold and uranium deposits by drilling. Prospecting for sulphide deposits was undertaken in the Boundiali, Toulepleu and Aboisso areas. This mainly consisted of an airborne electromagnetic prospecting program carried out by the Canadian company Terra Surveys Ltd. Many conducting bodies were found, and will be the object of future drilling.

Alluvial mineral prospecting work carried out in the Séguéla area allowed the identification in the concentrates of, among other minerals, gold and scheelite. Drilling in the Guéhiébli area was carried out to test geochemical anomalies (copper and molybdenum) and geophysical evidence was found. The sulphides revealed are essentially pyritic with chalcopyrite and secondary types of pyrite.

Uranium exploration was carried out in the north of the country, notably in the Odienné area. Thorium deposits generally are indicated. However, interesting uranium grades have been revealed by several borings in the granitoid substratum.

BRGM, in 1981, holder of three research permits, tested certain preselected areas for anomalies. This work was aimed at finding sulphide group elements (copper, lead, zinc, silver) in the volcanic sedimentary basin of Birrimien, as well as gold and uranium.

Petroci continued a carborne spectrometry survey in the regions of Bouaké, Boundiali and Odienné without significant results. Henceforth, the uranium division of this company will be transferred to Sodemi, which will now be responsible for work in this section.

An exploration program by Comimat S. A. in the Tortiya area has resulted in the discovery of a diamond deposit. The government has granted a mining permit to the company, and development will start quite soon.

Comici has obtained three permits to search for gold in the Tabou area. It undertook prospecting with the objective of studying the various formations likely to contain mineralization: quartz seams, elluvials and alluvials, most particularly the Nero alluvials.

In 1981 the government decided to evaluate the gold deposit of Ity. The project financing will be settled in 1982 following the creation of a mining company. Mining will start in 1985.

KENYA

An area in the northwest of the country has been selected for particular exploration attention to establish its mineral potential. The area, of some 40,000 square kilometers (15,440 square miles), will be covered by an aerial geophysical survey.

The government has given permission

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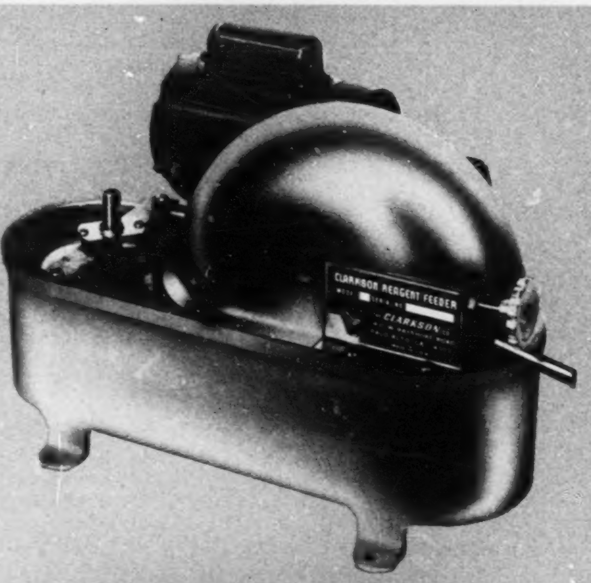

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for the construction of the country's third cement plant in the Keryo valley. An important limestone deposit was discovered there recently. Studies were carried out by Wescon Ltd. The new cement plant is expected to have a capacity of 500,000 metric tons.

A new mining company was formed in 1981, Octagen Minerals. The company operates a small talc mine at Weboye in the West Pokot region.

LESOTHO

At Letseng-la-Terai mine the ore treated last year was 1,889,000 metric tons, compared with 1,903,000 tons in 1980. The decrease was mainly a result of two prolonged interruptions to the power supply to the mine caused by extreme icing. The grade mined declined slightly to 2.8 carats per 100 tons for the year as a whole. However, during the fourth quarter it improved to 3.04 carats per 100 tons.

Diamond production was 52,921 carats, compared with 53,714 carats in 1980. Diamonds larger than 10 carats represented 12 percent of production.

Letseng has always been a difficult mine to operate, it is in a very isolated location, high in the Maluti Mountains, and is one of the lowest grade diamond mines in the world. Due to the depressed state of the diamond market, particularly for the larger high-quality stones produced by the De Beers Lesotho Mining Company, the mine has been operating at a loss for some time. Thus, it was no surprise when it was announced in May of this year that the mine was to close down.

Letseng was virtually the only mining operation in the country and one of the largest industrial employers. Its closure will be a severe blow to the country's economy. According to the last annual report, the main pit would have reached its planned final depth in August 1982. The satellite pit had a remaining life of about four years.

LIBERIA

The mining industry, with its heavy reliance on iron ore, continued to be adversely affected by the recession in the steel industry. Between 1970 and 1980 the value of the country's iron ore exports rose by 102 percent; however, operating costs rose by 253 percent. In the light of mounting financial difficulties and the continuing weak steel industry, many plans have had to be shelved.

Lamco has no definite plans to reactivate the Tokadeh expansion at Nimba and Bong Mining Co. has shelved its plan to develop its Zaweah II deposit. The National Iron Ore Company Ltd. (Nioc) is confining its investment to the rehabilitation of the Mano River mine.

Lamco's deliveries in 1981 amounted to 7,500,000 metric tons, about the same level as in 1980. The company expects that currently mined ore bodies will last until 1987-88. Plans for the extraction of other ore bodies are in hand; they envisage the mining and concentrating of Lamco's own ore in combination with the transportation of ore from Guinea on Lamco's railway and shipment through Lamco's docks. Lamco has signed an ore contract that gives 22 percent higher prices and expects to make a profit in 1982.

NIOC's plans for Mano River envisage an investment of some $50,000,000. The main objective is to improve the mine operation, including the transport of ore to the port of Monrovia. On completion of this modernization, output from the concentrator will be 3,250,000 tons per year, an increase of 30 percent over current capacity. Elsewhere, the deposits of Wologisi and Bea Mountain await the eventual decision for development to begin.

LIBYA

Sofremines is working on the development of the Wadi Shatti iron ore deposit. It is to be developed as an open pit mine with an annual production of 5,000,000 metric tons. The project also includes the

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construction of ore preparation plants, a 15-megawatt power plant, infrastructural facilities, and housing for 4,300 inhabitants.

In 1981, substantial contracts were awarded for the supply of equipment to the Misurata steelworks complex, on the coast some 180 kilometers (120 miles) east of Tripoli. The contracts include the construction of two complete electric steel melting shops. Melting shop No. 2 will have a capacity of approximately 650,000 tons per year.

MALAGASY

Investigations of uranothorianite in Fort-Dauphin and uranocircite in the lacustrine area of Antsirabe continued. Chromite production by Kraoma in Andriamena and north Befandriana continued at a level of around 150,000 tons per year.

Considerable attention was devoted to the Soalala iron ore deposit. It consists principally of three ore bodies containing an average 35 percent Fe. The deposits are 60 kilometers (37 miles) from the coast, near the Bay of Baly, which could accommodate 150,000-metric ton ore carriers.

Preliminary studies were carried out by Italsider, but the current investigation is being conducted by Bureau de Recherches Géologiques et Minières (BRGM). The program involves 2,500 meters (8,200 feet) of drilling and beneficiation tests.

MALAWI

The new Mines and Minerals Act came into force in March. It is hoped that this will increase mineral exploration and development. There are three categories of exploration license in the act for low, medium, and high cost operations. Non-exclusive prospecting licenses and mining claims, for example, are intended for the small operator, while mineral permits are intended for building materials.

Large scale exploration and mining activities fall under the third category, mineral rights. These comprise reconnaissance, exclusive prospecting, and mining licenses, and are granted and renewed by the minister. A reconnaisance license is valid for one year, is renewable, and can cover an area up to 100,000 square kilometers (38,600 square miles). An exclusive prospecting license is initially issued for three years with a right to two successive periods of renewal, each of two years. It also carries a right for the holder to be granted a mining license if a deposit is sucessfully proved. A mining license is valid for a period of up to 25 years and carries a right of renewal for an additional 15 years under certain conditions.

It is provided in the act that, at the time of granting an exclusive prospecting license, the government may enter into an agreement covering conditions not covered by the act. The restriction on uranium exploration by private companies was suspended after the enactment of the new legislation.

Lonrho (Malawi) Ltd. reported a breakthrough in its efforts to reduce iron impurity in strontianite and monazite concentrates. There was, consequently, some optimism that development of the large Kangankunde carbonatite deposits would finally go ahead.

British Gypsum Ltd. registered a local subsidiary, BPB (Malawi) Ltd., to mine vermiculite at Kaphirikamodzi, about 30 kilometers (18.6 miles) from Blantyre. A processing plant has been erected. Output, however, will remain at a low level until the viability of transport routes to Europe has been fully assessed.

MALI

Operations at the Kalana gold mine in the Sikasso region, some 300 kilometers (186 miles) southeast of Kati are to be expanded. The mine, operated by Société Nationale de Recherches & d'Exploitation des Resources Minières (Sonarem), currently produces about 400 kilograms (12,860 ounces) per year.

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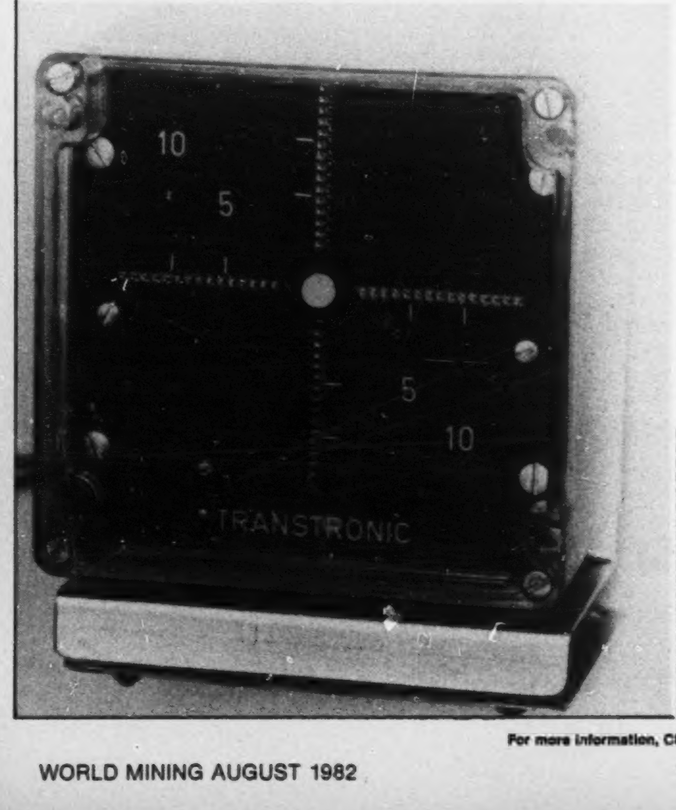

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annual output to between 1,800 and 2,000 kilograms (57,870 and 64,300 ounces) of gold and 500 kilograms (16,075 ounces) of silver. The reserves are estimated to contain 30,000 kilograms (964,500 ounces) of gold.

Bureau de Recherches Géologiques et Minières (BRGM) has conducted some diamond exploration in the country and also a search for gold in the regions of Kéniéba and Kangaba. An exploration program is to start in l'Adrar des Iforas in northern Mali, covering the regions of Tessalit, Kidal and Tadhak. Prospecting will be carried out in a potentially polymetallic rich area of 15,000 square kilometers with United Nations aid.

MAURITANIA

Société Nationale Industrielle et Minière (Snim), the state company, mined and sold from the iron ore mine at Kedia du d'Jil, 6,030,000 tons of high-grade ore (plus-60-percent Fe) and 2,850,000 tons of siliceous ore (50 to 60 percent Fe) compared to 5,800,000 and 2,900,000 tons respectively in 1980.

The Kedia du d'Jil reserves have been confirmed. The Guelbs project is scheduled to go into production in 1984. For the first stage, at Guelb El Rhein, production is estimated at 6,000,000 tons per year, and in the second stage, that of Guelb Oum Arwaguen, production will total 12,000,000 tons annually, beginning in 1991.

In the long term Snim calculates that production will total 30,000,000 tons yearly beginning in 2000. Additional ore will come partly from Tiris in the Zoverate region, and partly from Taziast in the Nouadhibou region. With this aim in view Snim has already undertaken reconnaissance and carried out research in these areas.

Kedia du d'Jil has been mined since 1961 and still has reserves of 50,000,000 tons of rich ore and 30,000,000 tons of siliceous ore. Guelbs El Rhein and Oum Arwaguen contain reserves of about 500,000,000 tons of magnetic ore, which can be concentrated by dry techniques. The grade of the ore varies from 37 to 40 percent Fe.

MOROCCO

The mining industry, which relies predominantly on exporting its products, remained sensitive to the present international economic situation. But, in spite of the unfavorable economic climate prevailing in 1980 and 1981, the weak economic growth, a lively increase in the interest rate and high inflation, mining activity was able to maintain its position in the national economy. This was due partly to development of production capacity and increase in exports by the Office Chérifien des Phosphates (OCP) and by the private mining sector, and partly because of the increase in the price of phosphate and its by-products, and the increased strength of the dollar and the pound sterling, in which the minerals are sold on the international market.

The value of exports by the mining industry, including phosphate by-products, rose in 1981 to $1,262,000,000, an increase of 40 percent compared to the previous year.

In accordance with the five-year plan, 1981-1985, mineral research concentrated on developing exploration for coal, lignite and uranium, precious metals and industrial minerals.

Uranium exploration drilling was carried out by the Bureau de Recherches et de Participations Minière (BRPM) at Wafaga in Marrakech province, and other evidence confirmed the presence of uranium in the Assaka region. Research showed three radioactive zones and other areas containing uranium in the Maroc Central and Anti-Atlas regions.

Research was also carried out to evaluate precious and strategic metals—gold, silver, copper, lead, zinc, wolfram and tin reserves.

Development and equipping progressed at the mines of Zgounder and Tiouit in Ouarzazate province and the Sidi Lahcen mine in the Oujda province. The Zgounder area has reserves of silver ore estimated at 400,000 metric tons, with a maximum silver content of 572 grams (18.3 ounces) per ton. It is envisaged that 56,000 tons of ore, with a silver content averaging 515 grams (16.5 ounces) per ton, will be mined per year. Reserves in the Sidi Lahcen area are estimated at approximatey 1,800,000 tons containing 6 percent lead, 0.58 percent zinc and 120 grams (3.8 ounces) of silver per ton.

Significant gold indications were discovered at Jbel Seghro in the Ouarzazate region. Silver mineralization was discovered in the Jebilet range. Two deposits were discovered, one at Rock blanc and the other at Jebil Khetem, central Morocco, containing 220,000 tons grading 500 grams (16 ounces) of silver per ton and 540,000 tons grading 50 grams (1.6 ounces) of silver per ton, respectively.

A total of $19,000,000 was invested in mineral research, $6,200,000 by BRPM and $12,800,000 by private mining companies. A further $5,610,000 were invested, by the OCP, in investigations on the Meskala, Sidi Hajjaj and, Khouribga deposits.

The OCP continued its program to increase production and extraction capacity at the Sidi Daoui, Ben Guérir and Youssoufia deposits. Preliminary work at the Sidi Hajjaj deposit was carried out to move onto the first production stage of 3,000,000 tons of phosphate per year, intended for export through the new port of Jorf Lasfar.

In other mining centers, projects that had been planned in the three-year plan, 1978-1980, have practically been completed according to schedule. The copper mine at Bleida achieved its full operating capacity, 800 tons per day, during October 1981.

Work was carried out at the lead and silver deposits at Sidi Lahcen; the gold, silver and copper deposit at Bougaffer and at the silver deposit at Zgounder. Production at these three deposits was scheduled to start in 1982.

Preliminary work was carried out on the polymetallic lead, zinc, copper, gold and silver deposit at Boumaadine; at the fluorite, barite, lead deposit at Zrahina; and at the wolfram deposit at Sidi Bouazouz.

Great effort throughout the year was put into developing small-scale mining projects by members of the mining cooperatives in the provinces in the south of the country.

Morocco needs sulphur for phosphate processing and is looking for rapid development to meet these needs in order to reduce, as far as possible, the dependance on imported sulphur. The mines department has commenced a study to build a sulphuric acid plant using gypsum from Safi.

In addition, OCP continued with the following major developments:

- The construction the fourth line MP 1 at Safi giving additional capacity of 500 tons of P_2O_5 per day. This unit started production in June 1981.
- The building of Maroc Phosphore II at Safi, which has a capacity of 1,500 tons of P_2O_5 per day, the first stage started prodution in September 1981.
- Carrying out of studies for the construction of plants, Phosphore III and IV at Jorf Lasfar, which will have a total capacity of 4,000 tons of P_2O_5 per day.

Moroccan mineral production in metric tons

Commodity	1979	1980	1981
Phosphate rock	20,036,000	18,758,495	18,562,160
Coal	710,000	680,000	703,000
Iron ore	61,739	78,020	49,854
Manganese dioxide	135,167	130,662	109,647
Lead concentrate	165,288	171,377	168,406
Zinc concentrate	12,908	21,443	14,669
Cobalt concentrate	8,008	6,709	6,265
Copper concentrate	23,657	20,447	23,304
Barite	286,667	358,311	463,869
Pyrrhotite	197,115	124,575	76,225
Fluorine	63,200	54,400	66,700
Antimony ore	1,977	1,278	1,120
Silver precipitates[1]	33,345	24,897	—
Silver metal[1]	10,573	12,622	40,381

1. Kilograms. 1.0 short ton = 0.907 metric ton. 1.0 metric ton = 1.10 short tons.

capacity of 4,000 tons of P_2O_5 per day. Start-up is anticipated sometime in 1983.

At the same time, OCP is continuing work to develop the first plant to extract uranium from phosphoric acid at Safi.

In other mineral sectors, most work concerned lead with the construction of a reverbatory furnace at at Oued El Heimer for the treatment of copper dross. The Oued El Heimer smelter is now capable of treating half the country's lead concentrate production.

Technical-economic and feasibility studies were carried out at the central lead smelter and the Moroccan copper smelter.

MOZAMBIQUE

The Direccão Nacional de Geologica has embarked on a mineral inventory of approximately 275,000 square kilometers (106,200 square miles) of the country. Exploration is being carried out by Hunting Geology and Geophysics Ltd. The first phase included 344,000 line kilometers (213,800 miles) of gammaray spectrometry, coupled with photogeology and interpretation of Landsat data. Interpretation of the airborne magnetic and spectrometric data collected during 1981 continues and flying has been resumed for the 1982 season. The preliminary interpretation of aerial photography and Landsat imagery is complete and when combined with the airborne geophysical results will be used as a basis for ground follow-up in the 1982 dry season.

The field work for the second phase of the three-year project will involve geological mapping, reconnaissance geochemistry, prospecting and, later in the field season, ground geophysical surveys in areas of interest. At present a geochemical laboratory is being set up in Tete and is expected to be operational very soon.

After the 1982 field season, Hunting will commence interactive computer processing of Landsat data, using the Hipas system, to help in the identification of target areas for ground work in the 1983 field season. Regional geological maps of the survey area will be completed during 1982 and 1983.

NIGER

The mining sector for a long time played a marginal role in the economy of the country, representing less than 1 percent of the gross domestic product. Up to 1971 the production of cassiterite, at about 130 metric tons per year, was the most important mineral resource. Nowadays, though, Niger is among the top five uranium producing countries in the world. The objectives for the future include an increase in production to over 10,000 tons of uranium metal per year, through the opening of four new mines, by the year 1990. Production in 1980 was 4,180 tons and the target was for 4,500 tons in 1981.

It is planned that four deposits will be developed as mines this decade. Two, Tassa N'Taghalgue and Abkorum-Azelek, should be producing at full capacity by 1986. The investment required is expected to be in the neighborhood of $115,000,000 for each mine. The development of the other two, Imouraren and Afasto-Ouest, depends on future supply and the world market. It is not absolutely definite that these two mines will be developed. Two other deposits, Afasto-Est and Adrar, are also being studied.

Cassiterite production, from smallworkers, has tended to decline over recent years. By 1979 it had fallen to just 89 tons. It is intended that a level of 90 tons per year should be maintained in the immediate future.

Phosphate, from the An Akker deposit in Tahoua region, is also produced by smallworkers. Output is running at about 4,000 tons per year. It is hoped that production from this region can be raised to about 6,000 tons. A further aim is to develop the Tapoa deposits for production during the second half of the decade. The preliminary planned capacity is 200,000 tons.

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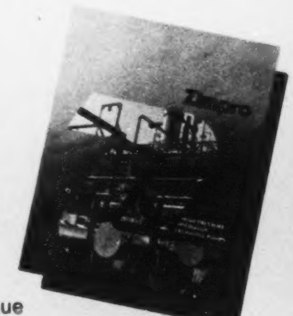

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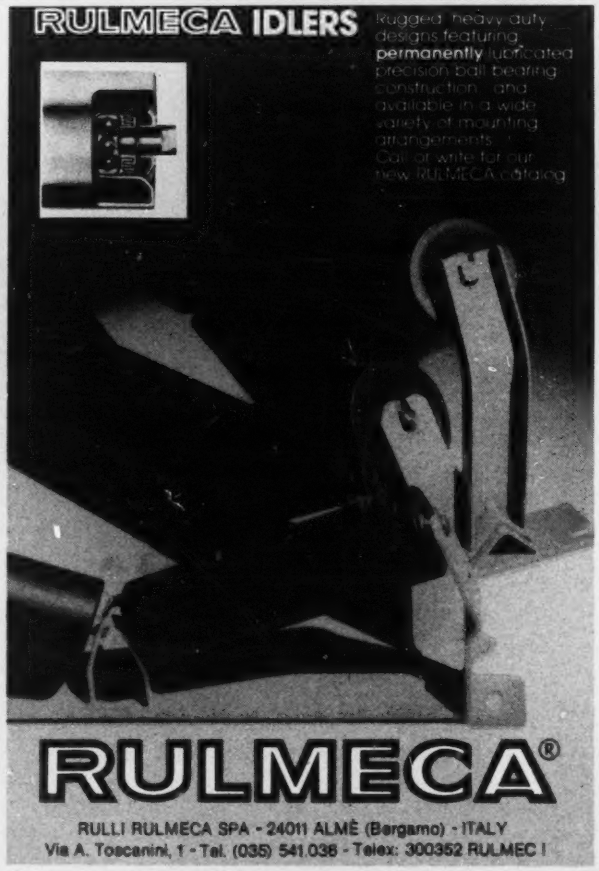
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Recent exploration revealed this major phosphate deposit 150 kilometers south of Niamey with reserves estimated at more than 500,000,000 tons. This is currently subject to a detailed study. If the results are favorable, it is expected to cost some $70,000,000 to bring into production.

In the Say region there are reasonable iron ore resources, estimated at some 20,000,000 tons grading 48 to 53 percent Fe. It is hoped that it will be possible to develop an iron ore production of 1,000,000 tons per year by 1990, depending on the results of a $3,500,000 feasibility study underway.

NIGERIA

Development of the Itakpe iron ore deposits continues with the aim of production starting in 1983, at a rate of some 7,000,000 metric tons of iron ore per year. About 4,000,000 tons of high-grade concentrate will be produced each year, during the first phase. The complete project is being developed by the Associated Ores Mining Company Ltd. (AOMC) with technical expertise provided by Sofremines. The development of Itakpe is crucial to the country's iron and steel plans.

Almost half of the $9,500,000,000 set aside for the manufacturing sector in the 1981-85 plan has been allocated to the iron and steel industry. The Warri plant, some 320 kilometers (200 miles) south-east of Lagos, has started steel production. The largest of the projects is the Ajaokuta blast furnace plant, which will have an intial output of 1,500,000 tons. It is estimated that the production from Itakpe will be sufficient to serve both these plants.

Amalgamated Tin Mines of Nigeria Ltd. started the year with reserves of 37,068 tons of ore at an average grade of 0.384 kilogram per cubic meter. Total production for the 12 months ending March 31, 1982 was 1,668 tons of tin concentrate and about 110 tons of columbite concentrate.

Alluvial sources have, hitherto, supplied all the cassiterite mined, but annual production has fallen by more than 50 percent over the last decade, to below 4,000 tons. The major factors are the depletion of the easily mined, high-grade alluvial reserves, the slow introduction of mechanization, increased operating costs, and the absence of alternative reserves.

Primary deposits offer good prospects to increase reserves, and the Nigerian Mining Corporation (NMC) is exploring such possibilities. There are also large known reserves of sub-basalt cassiterite, and the prospect for further such reserves is high. These two sources offer great potential for production expansions. Similarly, future exploration is expected to increase alluvial reserves and activity in that sector.

The Nigerian Uranium Mining Co. (Numco) is to begin mining a uranium deposit in Bauchi state, in the northeast of the country, in 1982. Major reserves of iron ore and marble have been discovered in Plateau state, 10 kilometers south of Abuja. The marble deposit forms a contact with the iron ore over a length of 20 kilometers and a width of approximately 300 meters. It appears, after preliminary investigations, that the marble resources are of greater importance than the iron ore.

Other developments include trial gold mining at Ilesha after initial results suggested mineable reserves of 311 kilograms (10,000 ounces). Exploration has also started in the northwest of the country. The NMC is involved with an exploration program for lead and zinc in the Abakaliki area.

RWANDA

This country's mineral production is based on cassiterite and wolfram, and to a lesser extent on columbo-tantalite, beryl, and gold. Mining is carried out by Société des Mines du Rwanda (Somira) and independent artisan miners.

The Bureau de Recherches Géologiques et Minières (BRGM) is carrying out a third phase of detailed prospecting to find extensions of targets discovered in previous phases in the north east. The Projet de Recherches Minières du PNUD is exploring the rest of the country for gold, cassiterite, wolfram, uranium, etc.

Early in 1982 a tin smelter, situated near to the capital of Kigali, went into production. Its initial capacity is 3,000 metric tons per year.

SENEGAL

The reserves of the Falémé iron ore deposit have been estimated at about 380,000,000 metric tons of oxide ore with a further 287,000,000 tons of magnetic ore. The feasibility study will be completed in 1983, but already a mining rate of 12,000,000 tons of oxide ore per year for more than 20 years is being discussed. The pre-feasibility study suggested an investment of more than $800,000,000.

Bureau de Recherches Gèologiques et Minières (BRGM) carried out an investigation of the Sabodala gold deposit, 600 kilometers from Dakar. The work showed that there are 900,000 tons of ore containing 5.75 grams (0.18 ounce) of gold per ton. There is a second, small deposit close by with an estimated total gold content of 2 tons. Mining of these deposits is scheduled to begin in 1986.

During the current fifth plan, La Compagnie Sénégalaise des Phosphates de Taiba (Cspt) will invest some $30,000,000 to increase the capacity of the Keur Mor Fall pre-treatment plant. Cspt's planned production for 1981 was 1,750,000 metric tons of phosphate of lime. This is to rise to 1,800,000 tons in 1984 and 1,900,000 tons in 1985. Société Sénégalaise des Phosphates de Thiès (Sspt) has recently developed a process to upgrade the quality of its aluminum phosphate.

Industries Chimiques du Sénégal has awarded contracts for the design and construction of phosphoric and sulphuric acid plants to be located near Taiba mine. The phosphoric acid unit will have a maximum capacity of 800 tons of P_2O_5 per day, while the sulphuric acid unit will have a maximum capacity of 2,100 tons per day.

Cogéma is continuing with its exploration for uranium. No significant results have been achieved to date. Despite recent, positive studies, no private company has shown any interest in developing a marble mining industry within the country.

SIERRA LEONE

The world recession prevented any noticeable improvement in the overall economy of the country. There was a fall in the production and export of diamonds, though slight increases were recorded in the production and export of rutile.

Production of diamonds by the National Diamond Mining Company (Sierra Leone) Limited was 160,271.4 carats, of which 14,947.0 carats were from the kimberlite deposits, mostly the No. 1 kimberlite pipe. Open cast mining started at the No. 2 kimberlite pipe. Illegal mining was contained by the company's security forces in the unmined areas and in current mining blocks of the Yengema and Tongo leases. Under the Alluvial Diamond Mining Scheme, 305,356 carats of diamonds were exported in 1981.

The Sierra Leone Government and Sierra Leone Selection Trust were negotiating an agreement on kimberlite mining in Sierra Leone. These negotiations were progressing at the end of the year.

A total of 615,994 metric tons of bauxite were produced by Sierra Leone Ore & Metal Company with exports amounting to 609,625 tons, mainly to West Germany and the United States. The 1981 production and export figures were below those for 1980.

The erection of a new washing plant was completed at Gondama, 20 miles south-east of Makanji, where the former washing plant was closed down. The company completed the following installations: a new power station; a dryer; 800 meters (2,625 feet) of conveyor installations; storage facilities for dry bauxite at the port of Nitti; a 200-meter (656-foot) bridge over the Jong river; a 15-kilometer (9.3-mile) road from Nitti to Gondama; and a 50-kilometer (31-mile) overhead power line. Operations at the new Gondama plant started in December 1981.

Sierra Rutile Ltd. produced 53,481 tons of rutile from 4,994,550 tons of ore. Exports totalled 50,662 tons, all to Europe and the United States. Significant improvement in the performance of the dredge occurred after the installation of additional screen capacity and the change from 19 to 13-millimeter (0.75 to 0.5-inch) Linatex screens. At the port of Nitti a major new jack-up barge repair facility was being constructed and nearing completion by the end of the year.

In July 1981 the iron ore mine at Marampa was taken over by the Marampa Iron Ore Mining Company, a government-owned company, with Austromineral of Austria as managers and executive sales agent. Reassessment of the available mining reserves revealed that there were at least 13,000,000 tons of proved and developed primary ore in the open pits of Masaboin and Ghafal. This did not take into account ore in the tailings. The average Fe-content was 38 percent.

All basic engineering work was completed, and cleaning and surveying of the rail line between Marampa and Pepel was carried out; it was found that reopening of the line would not be difficult. It was not envisaged that the rehabilitation of the reclaiming, loading and operating facilities at Marampa and Pepel would present any major problems.

The number of licenses issued to Sierra Leoneans for alluvial gold mining was 38. Exports amounted to 123 kilograms (3,948 ounces). All gold mined in the country must, by a law enacted in October 1981, be sold to the Central Bank of Sierra Leone, which is the country's sole gold exporter.

Sierra Leone mineral production in metric tons

Commodity	1979	1980	1981
Diamonds[1]	884,601	594,245	465,627
Bauxite	672,000	830,500	615,994
Rutile	10,700	52,573	53,481

[1] Carats. 1.0 metric ton = 1.10 short tons. 1.0 short ton = 0.907 metric ton.

SOMALIA

The ministry of mineral and water resources carried out a carborne radiometric survey in the Nugal area, to the north of the known uranium deposits of Mudug. Several small anomalies were found and the survey continues.

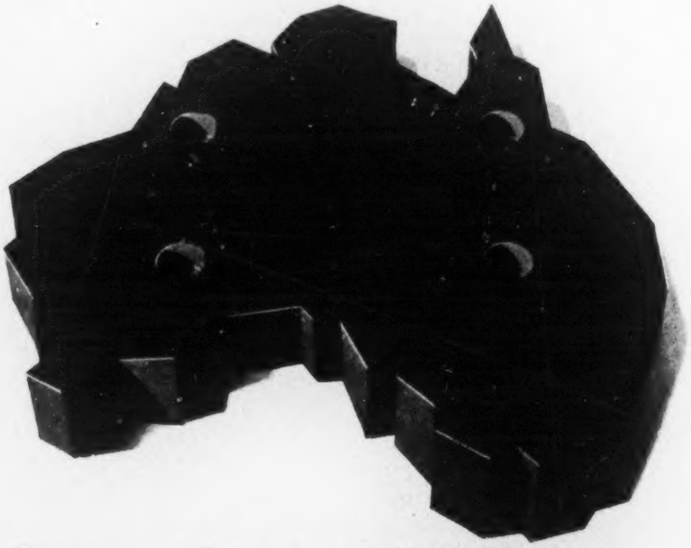
Investigation of the Qoljeit lead-zinc prospect continued and samples taken showed good grades. To further evaluate the potential, geochemical exploration was carried out, but the results are not known yet.

Iron ore reserves of approximately 180,000,000 metric tons are known to exist in the Bur area. Geological mapping of the area was carried out and several iron ore bodies were revealed that will add to the tonnage of the known reserves. Mapping continues over the whole area adjacent to the deposits.

The Somali Arab Mining Company (Soarmico) was established, some time ago, as a joint venture between the government and the Arab Mining Company (Armico), headquartered in Amman, Jordan. Subsequently the government of Iraq became a holder of one-third of the company's shares. The company's major objective is to explore for and mine radioactive minerals in Somalia.

Most activity in 1980 was concentrated on developing processing techniques for the somewhat unusual ores that have been found. One section of the concession area has been set aside for a thorough investigation since it has reserves sufficient for mining and is representative of all the different types of deposit in the concession area. An exploration program and geological map were prepared and airborne radiometric surveys were flown in 1981.

Exploration is currently concentrated on the Dusa Mareb area, 400 kilometers (250 miles) north of Mogadishu. The deposits are close to the surface and to a convenient road link with Mogadishu. The output of uranium ore is scheduled to reach 5,000 tons by 1982. Other de-



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posits have been found at Alio Ghelle, about 100 kilometers (62 miles) from Mogadishu, but these are too deep to be mined economically at present. The country's exact uranium reserves are unknown but a United Nations Development Programme (UNDP) produced in the late 1960's indicated 250,000 tons.

SOUTH AFRICA

The gold boom collapsed in 1981, reducing the value of total mineral sales by 30 percent to $13,800,000,000. The 1981 figure, which was still 10 percent higher than the 1979 result, was cushioned by a gradual adjustment of the rand against the dollar to a position of par at the end of the year. Gold production dropped to 656 metric tons compared with 674 tons in 1980 and 703 tons in 1979. The value of gold sales was 36 percent down from $13,400,000,000 to $8,577,000,000.

Diamond sales dropped sharply to $340,000,000, reflecting the poor market in gems. Production was cut back at the mines to 9,525,000 carats from the previous level of 14,700,000 carats.

Gold mine profits were severely affected by sharply higher costs and a lower gold price, which could not be offset by the weaker rand. Costs rose at nearly 20 percent. Up to 1985 the gold and uranium mines alone intend to spend about $7,300,000,000 on capital projects. It is estimated that this expenditure will create new jobs for about 6,100 skilled and 76,000 unskilled workers.

Vaal Reefs is to exploit the low grade Ventersdorp Contact Reef via the No. 9 shaft in its western section (formerly Western Reefs). This will lengthen the life of this large mine. This shaft, along with Free State Geduld's No. 5, will be the largest shaft in the world. Vaal Reefs, which already treats 8,000,000 tons a year and produces nearly 10 percent of South Africa's gold and 25 percent of its uranium, is also reportedly looking to a future with a No. 10 shaft in the southern area, which would extend the mine's life well into the 21st century.

Western Deep levels is developing the No. 1 shaft. Full production at the increased mining and milling capacity will be in 1986 after $450,000,000 of capital expenditure. Total capital spending necessary as a result of the expansion is estimated at $750,000,000 to give the mine a very long life.

Gold Fields has pushed through the massive merger of East and West Driefontein mines, and the inclusion of a new North Driefontein area. The new mine will produce more than 80,000 kilograms of gold a year, making it, probably, the world's largest producer.

In the Gencor group, Buffelsfontein is going ahead with its huge new Strathmore shaft to exploit its eastern area. Capital expenditure this year will be an estimated $50,000,000. At President Brand, the new No. 5 shaft, due to be commissioned in 1986, is being sunk at a cost of $125,000,000. Western Areas has installed the world's largest carbon-in-pulp plant to improve gold recovery.

Large quantities of uranium have been stockpiled. Production of uranium oxide was 7,234 tons in 1981 compared with the 7,252 tons produced in 1980. Production was mainly from 19 plants fed by 20 mines. Gencor's West Rand Consolidated Mines stopped uranium production.

Sales of Platinum group metals continued in the doldrums. Impala Platinum is cutting production by 10 to 15 percent in an effort to improve the world supply and demand imbalance. Production is running at about 940,000 ounces per annum.

Both Impala and Rustenburg Platinum Holdings have been able to resist cutting their producer price, despite the fall in the free-market level, due to long-term contracts with customers. Rustenburg has deferred plans to expand the Amandebult section. Production levels were reduced at Rustenburg's three major mines—Amandebult, Rustenburg and Union.

Exports of chrome recovered to 1,171,000 tons but the market is still depressed with a large stockpile accumulating. Production was 2,869,000 tons. Rand Mines, the mining arm of Barlow Rand, is poised to take advantage of any up-turn in the chrome market, but is containing expansion plans because of the depressed world market.

The world's largest chrome mine, Winterveld in the Eastern Transvaal, contains about 10 percent of the world's estimated 4,300,000,000 tons of chrome ore reserves, but is producing less than half its maximum output.

South African metal and mineral production in metric tons

Commodity	1979	1980	1981
Gold[1]	703,473	674,000	656,000
Silver[1]	100,664	96,950	235,393
Diamonds[2]	8,384,332	8,593,806	9,525,900
Copper	140,591	199,879	199,424
Tin	2,697	2,914	2,811
Antimony concentrate	20,086	22,378	9,810[3]
Chrome ore	3,296,962	3,296,960	2,869,502
Iron ore	27,497,549	22,911,987	28,318,856
Zinc concentrate	107,646	N.A.	87,172[3]
Manganese ore	5,182,343	5,710,839	5,039,687
Asbestos	249,187	268,636	235,943
Fluorspar	451,112	504,981	496,521
Pyrite	318,753	N.A.	N.A.
Uranium oxide	5,637	6,146	7,234
Phosphate ore	19,296,319	19,535,799	17,712,436
Phosphate concentrate	N.A.	N.A.	1,085,940
Coal	103,757,866	122,729,490	130,267,209
Gypsum	377,467	442,896	554,827
Limestone and lime	14,127,101	15,000,000	23,358,397
Silica	1,375,780	1,400,000	1,386,848
Vermiculite	191,573	185,699	190,601

1. Kilograms. 2. Carats. 3. Metal in concentrate. N.A. Not available. 1.0 metric ton = 1.10 short tons. 1.0 short ton = 0.907 metric ton.

SOUTH WEST AFRICA

The economy of the country has undergone a major slump due to the weak markets for uranium, base metals, and diamonds. The latter being the most critical blow. It is estimated that diamond revenue in the 1981-82 financial year will have been halved from the previous level of $143,000,000.

The four production plants and two remaining field screening units of CDM (Proprietary) Ltd. operated at full capacity for the first five months of 1981. Then, due to the depressed market, mining and treatment operations in the No. 3 plant area were suspended; both field screening units and the 50G sampling plant were shut down. Total tonnage treated fell to 12,544,000 at an average grade of 9.95 carats per 100 tons. Diamond production fell by 20 percent from 1,559,885 carats in 1980 to 1,247,960 carats in 1981.

Production of ore from Rössing Uranium Ltd.'s open pit mine was reduced by over 9 percent, 16,423,000 metric tons compared with 18,097,000 tons in 1980, but uranium oxide output was maintained at a similar level. In 1981 5,160 tons were produced compared with 5,250 tons in 1980. Efficiencies continued to improve and recovery also showed further improvement. An exploration unit was established in 1981 and prospecting teams are currently active in various parts of the country.

Johannesburg Consolidated Investment Company Ltd., in conjunction with B & O Minerals Ltd., is sinking a shaft in the Hope prospect of the Namib desert to explore for copper. A first level has been established 100 meters (328 feet) below surface and a second is being developed. Further development and drilling will be required to establish the configuration of the lens, which is expected to assay nearly 4 percent Cu.

T. O. N. M. Oil and Gas Exploration Corporation acquired a 50-percent interest in African Coast Diamond and Minerals (Pty) Ltd. (ACDM). It holds mining rights to an area of some 230 square kilometers along the Atlantic coast. The present plant, situated between the Hoarusib and Hoanib rivers, is being modernized to double its throughput to 100 tons of ore per day. Reserves are variously estimated to be between 2,000,000 and 6,000,000 carats.

Both Rosh Pinah and Uis mines were able to increase production last year. Production from Rosh Pinah was 47,200 tons of zinc concentrate and 20,200 tons of lead concentrate. At Uis, production of tin concentrate rose by 14 percent to 1,220 tons.

Late in 1981, Southern Sphere Mining and Development Company Ltd. purchased Tantalite Valley Minerals (Pty) Ltd., a producer of tantalite, mica, quartz, and lithium in the Warmbad district. Southern Sphere has also been carrying out preliminary studies of other potential areas. One deposit is reported to have been found that could have an initial tantalite output of 18,140 kilograms (40,000 pounds). Metallurg Inc. is also prospecting for tantalite in the country.

SUDAN

This is the largest country in Africa and has abundant mineral potential. Initial surveys are undertaken by the geological and mining resource department of the ministry of energy and mines. The subsequent tasks of studying feasibility, extracting ores, processing, and marketing are carried out by the Sudanese Mining Coporation (SMC). It has carried out its own small-scale exploration of tungsten, copper, kyanite, wollastonite, asbestos, and industrial mineral prospects.

The SMC's main operations concern the mining and marketing of mica, gypsum, and chromite. The SMC mines chromite in the Ingessana Hills, through the Ingessana Hills Mines Corporation, from four mines. There is also a small, private operator, the Nile Chromium Corporation, with an annual production of about 8,000 metric tons per year from one mine. In 1979/80 a peak 24,000 tons were produced by SMC but subsequently output fell, to 20,540 in 1980/81, short of the 25,000-ton target. Due to transport difficulties, one of the scourges of the African continent, large chromite stockpiles exist far from the shipping outlet of Port Sudan.

The SMC took over a mica operation in 1977. Ouput is currently just 1,000 tons per year. Gypsum is mined in the Red Sea Hills where reserves are reported to be 220,000,000 tons. SMC produces some 6,000 tons annually from one operation and two private companies produce a similar quantity between them.

Three significant iron ore deposits have been investigated recently. At Sofaya in the northern Red Sea Hills reserves are estimated at 14,000,000 tons containing 41 to 56 percent Fe. To the south, at Karrora, reserves are estimated at 14,000,000 tons at 40 percent Fe. The Fodikwan deposits on the Red Sea shore, 317 kilometers (197 miles) from Port Sudan were mined during the 19860's. Reserves are estimated to be between 2,000,000 and 3,000,000 tons with an iron content of 50 percent.

Alluvial gold exploration has been undertaken in the south, near Kapoeta by a Belgian-Sudanese joint venture. Minex is to start small scale mining operations and rehabilitation of an old gold mine in the Red Sea region. Minex has also signed a contract giving it tungsten exploration rights in the region of Es Sabablouga in Khartoum province. The Jebel Eyab tungsten prospect is thought to have potential and is under investigation by Bureau de Recherches Géologique et Minières (BRGM).

Abeir-Kateib is an old gold mine, which has been leased to a private company. The company intends to reprocess the dump material, with a gold content reported to be 1.56 grams (0.05 ounce) per ton. There are then plans to resume mining from the veins. At the Sarakoit mine, three rich gold bearing lenses have been discovered, the gold content varying from 10 to 20 grams (0.32 to 0.64 ounce) per ton. Agreement has been concluded with an American company to carry out further investigations.

Prospecting by Johns Manville has revealed reserves of about 30,000,000 tons of asbestos at Ingessana. However, it is low-grade and there are no plans to mine it at present. Klockner has assessed reserves of kyanite at Jebel Gerein 60 kilometers northwest of Atabra, estimated at 300,000 tons. The deposit could support a small mining operation.

Exploration has been conducted over an area of 20 square kilometers (7.7 square miles) around the old Hofrat En-Nahas mine. Proved copper reserves amount to 5,145,800 tons at a grade of 4.11 percent Cu and probable reserves amount to a further 4,170,630 tons at an average 3.98 percent Cu. A joint venture agreement has been consluded with a foreign partner for the evaluation and development of copper deposits and their associated minerals, gold and uranium.

The government has entered into an agreement with Compagnie Francaise des Pétroles (CFP) and Bureau de Recherches Géologique et Minières (BRGM) for the exploration and development of mineral deposits in the Red Sea Hills province in the northeast of the country.

In conjunction with Saudi Arabia, the Saudi-Sudanese Red Sea Commission is investigating metalliferous muds from the Red Sea. The Atlantis II deposit lies below 2,000 meters (6,562 feet) of water and extends over an area of 65 square kilometers (25 square miles). Reserves have been estimated at 1,700,000 tons of zinc, 400,000 tons of copper, and 5,000,000 kilograms (160,750,000 ounces) of silver. More testwork is required but by 1984, the Atlantis II mine could be in operation, involving shipboard mining and concentrating.

TANZANIA

Work on the Buck Reef gold mine is proceeding. This former producer in the Geita district, just south of Lake Victoria, is expected to start operations soon. It is thought that the mine's annual output will be around 284 kilograms (10,000 ounces) of gold per year. Another mine is being developed near Chunya, north of Lake Malawi, with a planned output of 160 kilograms (5,144 ounces) of gold per year.

A number of other new mining projects are in progress. One is an expansion of kaolin production from Pugu, some 40 kilometers (25 miles) west of Dar es Salaam. Production there was 2,800 tons in 1979 and the objective is to increase production to 5,000 tons using open pit techniques.

Phosphate mining is planned at Minjingu, at a planned rate of 100,000 tons per year, from an open pit. Technical assistance is being provided from Finland.

Elsewhere, the iron ore potential of Mchuchuma is being assessed with assistance from West Germany, and the open pit gypsum mining potential of Kilwa, on the coast some 250 kilometers (155 miles) south of Dar es Salaam is being examined with help from Sweden.

TOGO

This country has major reserves of phosphate, estimated to be 100,000,000 metric tons, sufficient for another 30 years of production at current rates. Production in 1980 was a record 2,932,845 tons of high quality material containing 79 to 81 percent triple phosphate of lime.

The Office Togolais des Phosphates (OTP) had planned to increase production to at least 3,000,000 tons in 1981. In fact, the original plans were for an even higher boost to production. However, the country's economic difficulties have caused a delay in the expansion plans. Last year one of the five treatment lines was shut down, and during the first six months of 1981 only 1,100,000 tons were produced.

TUNISIA

The country's production is currently running at about 9,000 metric tons each of lead and zinc metal, with associated amounts of fluorspar (about 36,000 tons) and barite.

KHD Humboldt Wedag is studying the Bou Jabeur mine for Société Tunisienne d'Expansion Minière (Sotemi). The objectives are to improve mining and processing methods, assess the mineable ore reserves, outline the potential to modernize and expand the mine, and to improve the infrastructure. The mine is based on a complex deposit containing lead, zinc, barite, and fluorspar.

A great deal of the country's fluorspar, particularly that mined at the Hamman Zriba mines, is processed to aluminum fluoride at the Gabes plant of Société des Industries Chimiques du Fluor. The annual capacity of this plant was 19,800 tons of aluminum fluorite, with a consumption of 31,086 tons of dry fluorite per year. Production in 1980 was 19,320 tons, while 1981 production is expected to have been 20,500 tons after some small improvements to the plant. All the production is exported.

Société Minière et Metallurgique de Tunisie's (SMMT) plant produces finished lead products from the metal produced by the Megrine smelter and also purchases the barite produced by various mines, grinds and bags it and sells it locally and overseas. The current production of barite is 30,000 tons per year. Plans are being considered to raise this to 90,000 tons per annum.

The department of mines is studying the possibility of treating the natural salines of Sebkhat de Zarzis. The principle aim is the production of potassium and magnesium.

UGANDA

The minerals industry represents but a small portion of the country's economy. The main source of wealth is agriculture, but small amounts of copper, tin, tungsten, and beryl are produced. Ownership and control of all minerals is vested in the government. The National Mining Corporation coordinates all prospecting, mining, and mineral marketing. Mining at present contributes only about 1 percent of the gross domestic product.

Historically, the Kilembe copper mine, which ceased operation in 1977, is the country's most important mine. In the early 1970's, Kilembe produced around 15,000 tons per year, and the Jinja smelter had a capacity of 12,000 tons per year. Seltrust Engineering has been contracted to carry out a feasibility study of the mine, concentrator, smelter, and cobalt and sulphuric acid plants.

The mine is served by a railway running from Kasese to Kampala. At Kasese rail head there is a stockpile of 1,200,000 tons of tailings, which may contain as much as 150,000 tons of cobalt. Much interest has been shown in retreating these tailings.

The government is to undertake a $4,500,000 study of the potential for mining of the Sukulu Hills phosphate deposits and the development of a full-scale phosphate fertilizer project. The deposits, 200 kilometers (124 miles) from Kampala, are high grade and close to the surface. Reserves are estimated to be 220,000,000 to 225,000,000 tons of ore, together with significant amounts of iron ore and bauxite. There is an old phosphate plant nearby at Tororo, which could be rehabilitated.

Rich iron ore deposits are reported to have been discovered in the Kigezi area, and exploration for uranium in the country is progressing. Tin and tungsten are found in the west of the country, and have been sporadically mined in the past; gold mining in these western districts has been banned.

Uganda is estimated to have some 4 percent of the world's known beryl ore reserves. Mining in 1977 produced around 50 tons of beryllium. Ore production is currently reported to be around 300 tons per year.

ZAIRE

The economic situation of the country continues to be grave. The external debt now totals over $4,500,000,000, a debt which the country is unable to service. Despite some rescheduling, arrears in payments reached $120,000,000 by the end of 1981, and further arrears of over $250,000,000 are forecast for 1982.

The mining industry forms an essential part of Zaire's economic output, with the principal mineral products—copper, cobalt, and diamonds—accounting for over 60 percent of export earnings. Thus, the current worldwide recession and the consequent depression of prices for these mineral products is not helping redress the poor financial position. In 1980 production of copper was 426,000 metric tons, cobalt was 14,400 tons, and that of zinc was 52,300 tons. Production in 1981 is expected to have remained at the same level.

Plans announced some time ago aimed at raising copper production to 470,000 tons per year. This is a modest figure compared with the targets of the second five-year plan (1975 to 1979), which envisaged copper production exceeding 570,000 tons and cobalt 18,000 tons. It was hoped, at that time, to continue the expansion further to reach 600,000 tons of copper and a massive 80,000 tons of cobalt. These targets were subsequently abandoned. More realistically, the forecast for 1982 was adjusted to around 450,000 tons of copper and 14,500 tons of cobalt. However, because of Gécamines' serious financial difficulties even these targets look doubtful.

One of the projects that was a casualty of the economic difficulties in the late 1970's was the P2 smelter and refinery development, which remains uncompleted. Loans for this have not yet been fully spent. Some of the funds have been spent in other areas thought essential to the maintenance of production. These include the development of the open pit at Dima, and a third rotary kiln at Kakontwe. Completion of the P2 expansion using the remaining funds is expected to start in 1983. If this occurs, copper production from Shaba province could increase by 100,000 tons a year.

Last year Dravo Engineers and Constructors completed the first phase of a mine planning and design project with Gécamines. The project involved seven different ore bodies and the design and evaluation of possible open pit mine designs and phases for each ore body.

The cloud of uncertainty that has surrounded the Tenké Fungurumé copper-cobalt project persists. However, progress on the Shaba-Inga power line, so critical to the mine project, was satisfactory. By mid-1981 over 80 percent of the work on the converter station at Inga and more than 60 percent of that at Kolwezi had been completed; the line may be completed this year.

The Tenké project was originally planned in the early 1970's to have an output of 130,000 annual tons of refined copper and 6,500 tons of cobalt, but it was halted in 1976. Société Minière de Tenké Fungurumé is now led by Cogema, with a 26.5 percent holding. Plans for the project have been revised for a return to construction in 1982. Reports have suggested that planned output may be reduced to 30,000 to 40,000 tons of copper concentrate a year, to be sent to Gécamines for further treatment. Cobalt output would also be reduced to about one-third of the original target.

In 1981 the officially reported output of diamonds by La Minière de Bakwanga (Miba) was 5,700,000 carats; the Miba mine aims to raise production to 9,000,000 carats in 1982, before passing 12,000,000 carats per year beginning in 1983. This will require an investment of some $40,000,000. Total output of diamonds in 1981, which were sold through the government mineral sales agency Sozacom, is thought to have been around 10,000,000 carats.

Certainly the Zairian diamond industry seems to have survived its break with De Beers' Central Selling Organisation (CSO) quite successfully. One of the main reasons for this success is probably that over 70 percent of Zaire's output is in industrial grade diamonds, and demand for these has held up better than for other categories.

Last year the government put forward a tin mining recovery plan aimed at improving production and conditions, improving recoveries, and increasing research and prospecting. Production is currently around 2,500 tons per year. The two main producers have been Sominki, operating in the Kivu-Maniema region, and Zairetain, which operates in Shaba province. A new company, known as SMDG, started operations in 1980, working small alluvial deposits.

Enterprises Minières Zairoises is to restart tin and tungsten mining operations and last year concluded a contract with GKN Contractors Ltd. to refurbish and re-equip a number of mines. Value of the contract is $50,000,000; the project is scheduled for completion in 1985. An alluvial tin deposit at Kania contains more than 3,000 tons of cassiterite grading around 1 kilogram (2.2 pounds) per cubic meter. During 1981 agreement was reached whereby Société Minière de Kania (Somika) will develop and mine the deposit. Société Minière de Goma has also commenced mining of a small alluvial tin deposit at Kalimibi. Société Minière de Katondo is also reported to be embarking on a tin mining project.

Agreement has been reached with the government to proceed with the construction of an aluminum smelter near the Inga hydroelectricity complex on the Zaire River at Banana. The Aluzaire smelter will have an initial capacity of 150,000 tons per year. The $800,000,000 project involves a consortium of of European and Japanese partners, lead by Alusuisse. It is anticipated that construction will not start before 1984. Its alumina requirements would have to be imported. Guinea and Jamaica have been mentioned as possible sources.

ZAMBIA

The major event of the past year, and one of significance to the world copper industry, was the formation, in early 1982, of Zambia Consolidated Copper Mines Ltd. (ZCCM). The company, which sulted from the merger of Roan Consolidated Mines Ltd. (RCM) and Nchanga Consolidated Copper Mines Ltd. (NCCM), is the second largest copper producer in the world, after Corporación Nacional del Cobre de Chile (Codelco), with an annual output of some 600,000 metric tons of copper and around 3,000 tons of cobalt, although the latter will increase significantly in the future as a result of expansions currently underway. (Actual production from ZCCM's two constituents in 1981 was 560,188 tons of copper, and 2,570 tons of cobalt.)

The formation of ZCCM is intended to allow co-ordinated planning and direction of capital expenditure, extraction and production of the Copperbelt's eight mines. It is also hoped that the creation of a larger and financially stronger unit will make it easier to raise funds on the inetrnational money market. Shortage of technical expertise has been a problem in the past for RCM and NCCM, and the merger will allow those technical skills available to be better deployed. The same will apply to areas such as marketing, purchasing, and utilization of stores and specialist services. The new company intends to place greater emphasis on research and development, prospecting and exploration, and mine development.

At March 1981 ZCCM had total fully and partially developed reserves of 93,600,000 tons of ore grading 3.45 percent copper, a high grade by world standards. These reserves include some 28,400,000 tons averaging 0.17 percent cobalt.

Besides copper and cobalt, ZCCM produces lead and zinc from its mines at Broken Hill Division, Kabwe. The Imperial Smelting Furnace here was shut down for a lengthy period of maintenance during the first half of 1981 and resulted in a significant fall in output. Lead and zinc production for the quarter ending June 30, 1981 was down to 7,056 tons, a fall of 32 percent compared with the previous year. However, in the September quarter sales rose by 3,000 tons, compared with 1980, to 13,499 tons.

The country is to receive up to $60,000,000 in soft loans from the European Economic Community (EEC) to finance copper and cobalt production developments. Towards the end of 1981 it was estimated that the mines were losing a total of more than $25,000,000 per month as a result of the weak copper and cobalt prices.

A number of major capital projects continued to progress during the year. At Mufulira, work began on the East Shaft extension involving the sinking of two sub-vertical shafts from the 550-meter level to facilitate ore handling down to the 1,140-meter level. At Baluba, the second stage of development aims at increasing copper production from 27,000 to 50,000 tons per year by 1987. At Chambishi, a cobalt vacuum refining plant and an acid plant are being built.

At Rokana, the old cobalt plant is being expanded and modernized and a new roast, leach, and electrowinning cobalt plant is under construction, by Zambia Engineering Services Ltd. Commissioning of these new facilities will be completed in 1982. Also at Rokana Division, the main Mindola subvertical shaft is to be deepened by 300 meters to give access to an estimated 30,000,000 tons of ore, containing 2.45 percent Cu, lying below the present production level.

It was decided to proceed with the Tailings Leach Stage III project at Chingola, to recover some 35,000 tons of copper per year for 15 years from concentrator accumulated tailings. It is reported that the cost of copper production from this leach plant will be the cheapest in the world. Overburden stripping rates at Chingola's open pits have been increased from 18,200,000 to 24,000,000 bank cubic meters per year.

Mining will cease at the Bwana Mkubwa open pit, one of the country's oldest mining sites, in 1982. The ore has been exhausted.

Uranium exploration continues in a number of areas and is being carried out by Saarberg Interplan, Agip, and Cogema. Agip's most recently signed lease, for example, covers an area of some 13,500 square kilometers. It has also been reported that interest in uranium exploration has been shown by the United Kingdom.

Zambia Industrial and Mining Corporation (Zimco) announced that significant phosphate deposits had been discovered. There are two deposits, at Kaluwe in central province and Chilembwe in the east, with total reserves estimated to be about 200,000,000 tons. The grade of ore at Chilembwe, in particular, is reported to be high, containing 15 to 25 percent apatite.

During 1981 the Reserve Minerals Corporation (RMC) began recruiting staff with a view to resuming emerald mining. RMC was formed in the wake of an enquiry into emerald mining and marketing and the problem of illegal mining.

ZIMBABWE

Production of gold, the country's major mineral sales earner, increased marginally to 12,000 kilograms (385,800 ounces) in 1981. However, the mining industry in Zimbabwe is facing rising costs, restrictions on foreign currency allocations and increased taxation of the mining industry. In addition to the foreign exchange problems there are serious transport and skilled labor deficiencies, all contributing to a 6 percent reduction in the country's economic growth. The small mines form the backbone of the mining industry, but some 23 of the small gold mines were forced to close during 1981.

The government proceeded with its plan to attain greater control over the mining industry. This will be primarily through a state-controlled minerals marketing agency, which will have power over the whole of the country's mining output, an estimated value of some $500,000,000 last year. Debate continues but it is intended that the agency would either purchase mineral output directly, for export or internal sales, or approve sales contracts negotiated by private sector mining companies. Prime Minister Mugabe has continually stressed that this will not lead to a nationalization of the mining industry.

Rio Tinto Mining (Zimbabwe) Ltd. recorded lower profits in 1981 and a fall in sales revenue of 17 percent. Gold output was slightly higher than in 1981, with sales amounting to 752 kilograms (24,177 ounces) of bullion and 230 kilograms (7,395 ounces) of gold in concentrate. Development of the Renco gold mine proceeded according to plan and the expansion was commissioned in the first quarter of 1982. Its planned output is some 1,500 kilograms (48,225 kilograms of gold per year.

RTMZ's Empress mine was hit by ore dilution problems and lower than planned grades, leading to a fall in the output of copper and nickel. Sales were 2,705 tons of nickel, 2,647 tons of copper, and 229 kilograms (7,362 ounces) of precious metals in concentrate. Output in 1980 had been 3,511 tons of nickel and 3,022 tons of copper. The Zinca platinum pilot plant project proceeded satisfactorily.

Falcon Mines Ltd. suffered a drop in pre-tax profits of almost 54 percent. Ore milled at the Dalny mine increased marginally to 242,045 tons but the yield fell from 6.17 grams (0.20 ounce) to 5.67 grams (0.18 ounce) per ton. Thus, gold

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production fell almost 8 percent to 1,372 kilograms (44,110 ounces). Working costs rose dramatically from $41.79 to $58.21 per ton milled.

Falcon has progressed rapidly with the development of the Venice mine, ore from which is currently treated at Dalny at a rate of 5,000 tons per month. In early 1982 this was increased to 7,000 tons per month. Venice's own mill was due to be commissioned in April 1982. The plant has a capacity of 5,000 tons per month, to which it will build up and Venice will, in addition, continue to supply 7,000 tons per month to the Dalny plant.

In late 1981 Bindura Nickel Corporation acquired Shangani Mining Corporation and now operates four mines: Shangani, Trojan, Madziwa, and Epoch. In 1981 the latter three milled 1,780,000 metric tons, marginally higher than the previous year. However, lower grades at Madziwa and Epoch reduced the average grade milled to 0.58 percent, compared with 0.62 percent in 1980, and production of nickel in concentrate fell to 7,303 tons. Total group output, with the extra Shangani contribution, was 7,907 tons.

At the end of 1981, total proved, probable, and possible reserves of the group were 37,440,000 tons averaging 0.67 percent Ni. The new acquisition, Shangani, has the greatest reserves, with a total of 15,340,000 tons averaging 0.69 percent Ni, and a life in excess of 20 years.

Towards the end of 1981, eight important new prospecting orders were granted to four companies. The companies involved were Union Carbide Management Services (Pvt) Ltd., Prospecting Ventures, Corsyn Consolidated Mines Ltd., and Saarberg Interplan Uran. Aerial exploration for cobalt, copper, molybdenum, tungsten, gold, lead, zinc, coal, and uranium and other radioactive minerals was undertaken. The largest area, 34,000 square kilometers (13,124 square miles), was granted to Saarberg along the southern bank of the Zambezi.

Three asbestos mines were closed by Amiantus during the year: Filabusi, Belingwe, and Mashaba; and a further three by Asbestos Investments (Pty) Ltd.—Pangani, Boss, and Vanguard.

Zimbabwe production of metals and minerals in metric tons

Commodity	1979	1980	1981
Asbestos	260,000	250,900	247,600
Gold[1]	389,000	367,000	371,000
Chromite	541,800	553,500	536,100
Copper	29,600	27,000	24,600
Nickel	14,591	15,074	13,018
Silver[1]	977,000	949,000	857,000
Cobalt	204	115	94
Tin	947	934	1,157
Coal	3,188,000	3,134,000	2,867,000

1. Ounces. 1.0 metric ton = 1.1 short tons. 1.0 short ton = 0.907 metric ton.

BAHRAIN

Aluminium Bahrain (Alba) is now producing at a rate of 170,000 metric tons per year, following the start-up of two new pot lines in 1980. Construction of Gulf Aluminium Rolling Mill Company's (Garmco) facility is proceeding.

The Arab Iron and Steel Co. (Aisco) will establish, over three years and at a cost of some $330,000,000, an iron ore pelletizing plant in Bahrain using imported ores to produce 4,000,000 tons of 67 to 68-percent Fe pellets each year for sale among the Gulf states. According to a study by Aisco, the total direct reduction capacity of Saudi Arabia, Qatar, and Iraq will be 2,685,000 tons by the mid-1980's. However, consumption at that time will be 4,000,000 tons. Aisco aims to fill the gap.

BURMA

The Bawdwin mine, operated by the No. 1 Mining Corporation, continues to be the most important. It currently produces some 6,000 metric tons each of lead and zinc and over 12,450 kilograms (400,000 ounces) of silver per year. Bawdwin's output has shown a steady decline due to failing reserves. Recent work has been aimed at developing low-cost open pit mining methods to recover low grade ore. Reserves amenable to this are estimated at 30,000,000 tons assaying 3.5 percent Pb and 60 to 90 grams (1.9 to 2.9 ounces) of silver per ton.

The Heinze River basin tin dredging project got into full swing in 1981. Ore is mined by a new 378-cubic meter (494-cubic yard) per hour dredge designed by Osborne and Chappel for the No. 2 Mining Corporation. This was the first dredge to be built for operation in Burma for many years.

Offshore exploration, with assistance from the United Nations Development Project (UNDP), continues. Tin and tungsten deposits offshore, in the Gulf of Martaban, have been revealed.

The Monya open pit copper mine is now in production. Its planned output is 12,000 tons of ore per day, which is transported to a copper flotation concentrator at Salingyi. Lurgi has submitted plans to build a smelter on the property, at a cost of $30,000,000.

CHINA

The year 1981 was one of consolidation and modernization of mining and metallurgical operations in this country. The shift in emphasis from heavy industry to light industry in 1979 lowered production goals and actual production of many ores and metals.

Gold production has had a high priority for several years, and output in 1981 was higher than in 1980. New dredges operating in the rivers of the northeast provinces, as well as increased production of lode gold in Shandong Province, were the source of much of the added production. Canadian and English engineering companies made studies of methods to raise output at several of the larger mines in that province.

China has several of the world's largest rare earths deposits. Production of these elements was increased from the Bayan Obo mine in Nei Monggol.

The most important copper development of the year was the restart of the delayed construction of a new 100,000-ton per year smelter at Guixi, Jiangxi Province by Sumitomo Metal Mining Company. This smelter was part of teh total Dexing project, the largest unit of which was a planned 135,000-ton per day open pit and flotation mill. United States-based Fluor Mining and Metals prepared the overall plan, but the reorganization of priorities terminated plans for this giant mine. Copper production in 1981 increased to 225,000 tons, according to the latest information.

China is now the largest producer of refractory grade calcined bauxite in the world, and continued to ship to the United States, Japan, and Western Europe throughout 1981. A new calcining plant that uses two rotary kilns, with a capacity of 200,000 tons per year, was under construction in Henan Province. A new 40,000-ton per year aluminum smelter was completed in Guizhou Province during the year. This capacity will be doubled in 1982.

The Capitol Iron and Steel Corporation continued with its modernization program at its Beijing steel mill and its taconite mine and magnetic separation plant in Hebei Province.

China produced 28 percent of the world's tungsten in 1981, but much of this was sold by provinces outside the control of the China Metallurgical Import & Export Corporation. At year-end, their was interest in centering all export sales of tungsten and other metals in this agency in order to increase control of exports and prices.

This country has long been deficient in potash reserves production, and is a large importer of Canadian potash as a result of this. In order to lessen the dependence of imported potash, a study contract was being negotiated with Jacobs International of the United States to study the economic feasibility of recovering potash from the brines of Chaerhan Lake.

Exploration for mineral deposits became more sophisticated during the year, as the new Prime 550 computer and associated software from Geometrics of Sunnyvale, California, United States were delivered and installed with training by Geometrics staff members from Concord, Ontario, Canada. Scintrex Ltd.'s complete package of computer compilation of airborne geophysical data was in use by the Chinese Ministry of Geology, with training by Dataplotting Services Inc. of Don Mills, Ontario, Canada.

Chinese production of metals and minerals in tons

Commodity	1979	1980	1981
Gold[1]	200,000	300,000	400,000
Silver[1]	1,600,000	1,700,000	2,100,000
Copper[2]	185,000	200,000	225,000
Lead[2]	135,000	155,000	155,000
Zinc[2]	135,000	150,000	155,000
Coal	691,000,000	668,000,00	650,000,000
Iron ore	85,000,000	88,000,000	100,000,000
Aluminum	325,000	375,000	360,000
Tungsten	11,500	12,000	11,000
Bauxite, refractory	60,000	70,000	80,000
Bauxite	1,400,000	1,500,000	1,600,000
Tin	16,000	16,500	15,000
Fluorspar	390,000	390,000	400,000
Titanium, sponge	1,800	1,800	1,800
Pig iron	40,700,000	41,500,000	39,000,000
Steel	37,900,000	41,000,000	39,200,000

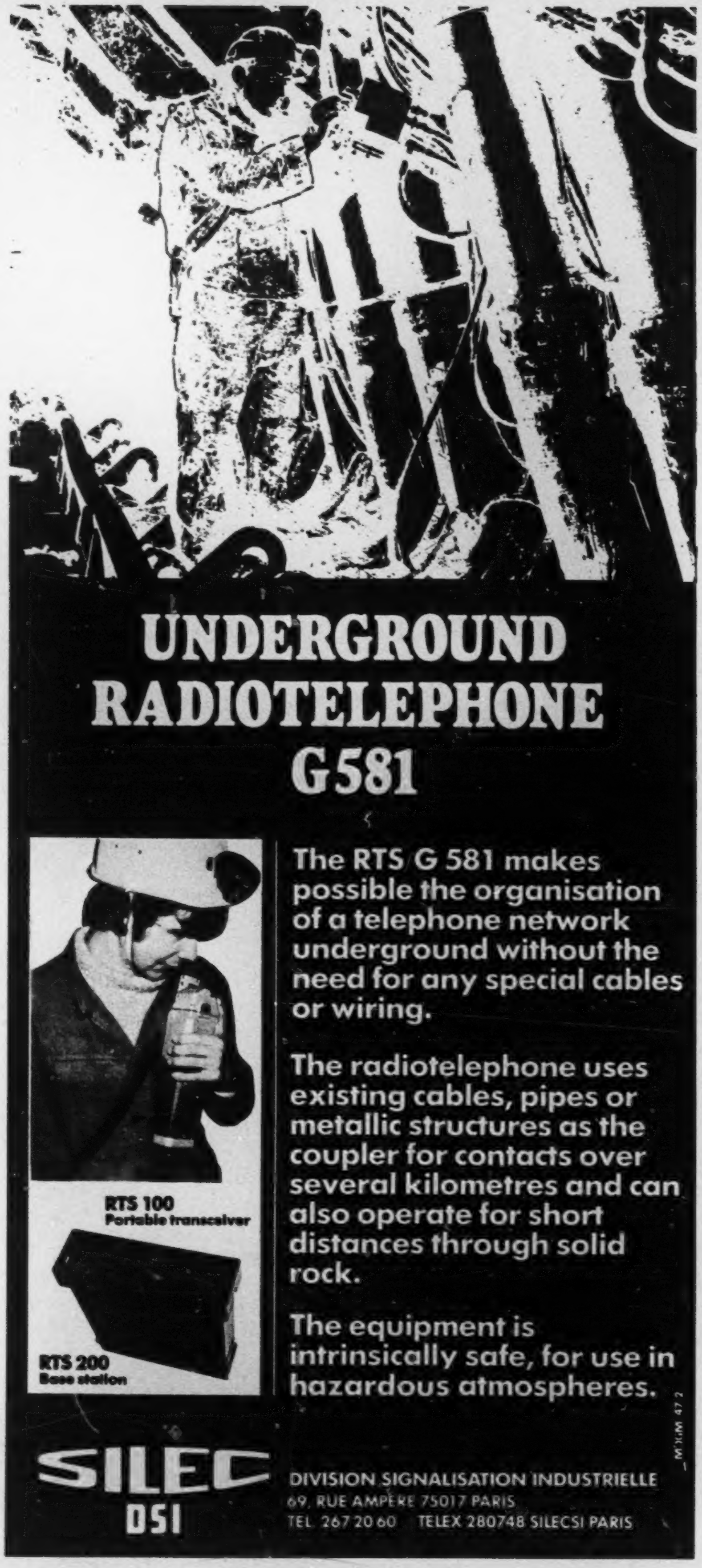
1. Ounces. 2. Mine production equivalent.

DUBAI

The aluminum smelter of Dubai Aluminium Company (Dubai) reached full capacity of 135,000 metric tons of aluminum per year in 1981. It is situated at Djebel Ali on the Arabian Gulf. The facility sets new standards of energy conservation. It uses natural gas from an offshore field as the fuel source, natural gas that was previously flared off. Each of the plant's 13 gas turbines has a waste heat boiler that harnesses turbine exhaust gases to produce steam for use in a nearby destination plant. The desalinated water, in turn, is used as process water by the smelter.

INDIA

As a result of regional, geological and geochemical surveys, there was a spate of new discoveries of tungsten mineralization associated with other valuable



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minerals and metals. A major belt containing tungsten, tin, fluorite, topaz, and molybdenum covering Abu, Sirohi, Pali, and Jalore districts of Rajasthan was discovered. A suitable block covering a 6-kilometer zone rich in tungsten and fluorite, near the village Belda in Sirohi district, was selected for detailed investigation. Another discovery of scheelite was made north of Raniket area in Almora district, Uttar Pradesh.

The Indian Aluminium Company developed a process to recover vanadium from alumina sludge and set up a commercial-scale vanadium recovery plant at Muri near Ranchi, Bihar. The first charge-chrome plant of 50,000 tons a year capacity of Ferro-Alloys Corporation at Randia in Belasore district in Orissa—being set up with assistance from Tanabe, Kakoki Company Ltd., and Okura Company Ltd.—was nearing completion. It will be a wholly export-oriented plant.

Indian production of ores, metals and cement in metric tons

Commodity	1979	1980	1981
Coal	103,364,000	109,102,000	122,478,000
Lignite	3,264,000	4,549,000	5,909,000
Bauxite	1,952,000	1,775,000	1,912,000
Chromite	309,841	320,622	334,681
Gold[1]	2,637	2,637	2,485
Iron ore	39,854,643	40,925,429	41,122,000
Lead concentrate	20,940	16,616	20,017
Manganese ore	1,770,568	1,666,467	15,000
Silver[1]	11,515	11,381	17,263
Tungsten concentrate[1]	38,547	94,107	37,738
Zinc concentrate	71,774	46,294	52,876
Apatite and phosphorite	681,486	542,907	561,944
Asbestos	32,094	32,468	24,515
Barites	490,699	434,015	353,362
Diamonds[2]	15,229	14,432	15,717
Dolomite	2,157,191	2,017,543	1,954,868
Fluorite concentrate and graded	21,495	21,207	22,905
Graphite (r.o.m.)	52,821	54,786	56,249
Gypsum	877,490	867,896	943,316
Kaolin	495,041	452,219	505,745
Kyanite	40,709	48,740	38,283
Limestone	31,317,161	29,211,296	30,873,000
Magnesite	396,211	385,104	453,410
Mica, crude	9,073	7,930	8,377
Pyrite	67,172	82,905	57,598
Sillimanite	16,108	14,488	10,254
Talc and steatite	361,862	331,647	329,149
Wollastonite	3,794	5,790	15,940
Steel ingots	9,936,000	9,358,000	10,269,000
Ferroboron[1]	1,336	460	—
Ferrochrome	22,249	16,494	31,066
Ferromanganese	186,803	158,308	208,836
Ferromolybdenum[1]	302,157	121,829	158,683
Ferrosilicon	53,087	54,319	60,253
Ferrotitanium[1]	128,540	321,233	170,107
Ferrotungsten[1]	22,861	21,206	10,744
Ferrovanadium[1]	190,608	92,262	112,505
Silico chrome	3,851	4,050	4,408
Aluminum	211,428	184,838	212,844
Copper (electrolytic)	14,707	17,021	14,764
Lead	9,820	14,846	14,325
Zinc	63,323	43,627	57,434
Cement	18,270,000	17,902,000	20,870,000

1.0 short ton = 0.907 metric ton. 1.0 metric ton = 1.10 short tons.

The Mica Trading Corporation (Mitco) opened a sales promotion office with stocking facilities in Belgium with a view to delivering mica to the end-users, especially the European market, in the quickest possible time. Mitco also signed a contract to set up a mica paper plant at Chadwara near Kodarma in Bihar with a total capacity of 1,200 tons per year.

IRAN

The situation in the Iranian mining industry remained tied to the general economic situation. There has been a decline in the economy mainly because, since the summer of 1981, oil revenue has not been sufficient to allow the purchase of new equipment or the proper servicing of old equipment. The economy lives essentially from day to day, relying on its production potential from before the revolution and it is now draining the stocks of spare parts and the like that were accumulated just after the revolution.

This situation has induced the authorities to recommence exports of non-oil items. Since 1981, exports of marble, zinc, and lead have restarted, whereas immediately after the revolution such exports were considered superfluous.

Production still remains good at the lead-zinc mine of Bafq, but the situation at Zandjan is not so good. Production within the lead and zinc mining industry is around 60 percent less now than it was before the revolution. Production of lead and zinc concentrates at that time were around 50,000 and 100,000 metric tons per year, respectively. The mining industry has now, largely, been nationalized and it is the ministry of mines that controls the principal mines.

The foremost mining project is still the Sar Cheshmeh open pit copper mine development. The construction of this large mine continued and the smelter and concentrator were started up with the help of Yugoslav technical experts. These installations are currently being commissioned. Most of the civil work for the refinery has been completed and the equipment has arrived on site. The refinery is expected to be completed by the end of 1982. The Sar Cheshmeh project was originally scheduled for completion in 1978 with a production capacity of 60,000 tons of copper per year.

IRAQ

Union Minière, acting as a sub-contractor to Sybetra, brought the Akashat phosphate mine into production during 1981. The annual output of the mine will be 3,400,000 tons of phosphate, but this could easily be doubled, without much additional investment, by working 24 hours instead of 12 hours per day.

The Akashat phosphate deposits are situated in the western desert of Iraq. The two deposits now being mined are horizontal and about 10.7 meters thick. Seam 1 contains 23,600,000 tons assaying 20.8 percent P_2O_5 and seam 2 contains 40,100,000 tons at 21.2 percent P_2O_5.

ISRAEL

Total mineral production here during 1981 was somewhat lower than the previous year as a result of the general weakening in the world fertilizer market.

Total phosphate rock production decreased by approximately 10 percent. At the end of the year the Negev Phosphate Company announced the closure of its calcination plant at Oron due to heavy financial losses. Other less energy-intensive processes of benefication are at present under examination. The wet phosphoric acid plant of the Rotem fertilizer complex was successfully commissioned and began production in August. Its rated capacity is 120,000 tons per year P_2O_5 content.

Israeli production of metals and minerals in metric tons

Commodity	1979	1980	1981
Phosphate rock	1,838,000	1,910,000	1,750,000
Calcined phosphate	377,000	490,000	460,000
Defluorinated phosphate	37,000	32,000	40,000
Potash	1,250,000	1,300,000	1,350,000
Cement	2,000,000	2,000,000	2,000,000
Magnesia (periclase)	38,000	41,000	35,000
Glass sand	107,000	135,000	120,000
Calcined flint clay	10,000	17,000	10,000
Bentonite	20,000	20,000	10,000
Cement copper	—	—	4,000

1.0 short ton = 0.907 metric ton. 1.0 metric ton = 1.10 short tons.

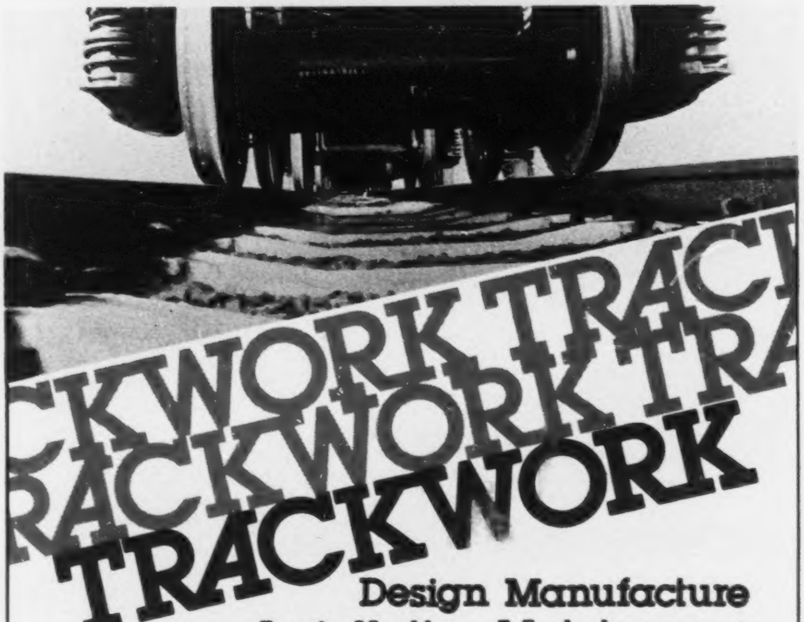
Potash production was slightly increased, as the new Makleff plant with a nominal capacity of 470,000 tons per year KCl was put into operation.

The Timna copper plant, reopened in October 1980, produced 4,000 tons of cement copper. Erection of the copper and manganese chemical plant continued, and is scheduled to begin operation by the end of 1982.

JORDAN

Proven and indicated reserves of copper, mainly in the Feinan district, now amount to approximately 60,000,000 metric tons of ore at an average grade of 1.36 percent Cu, with an average thickness of 2 meters (6.6 feet). Extensive feasibility studies have been carried out to evaluate the various metallurgical routes for recovering the metal.

The optimum route for recovering the Wadi Araba copper has been shown to be initial strong acid leaching, followed by thin layer leaching and solvent extrac-



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tion with a final stage of electrowinning.

The Natural Resources Authority is negotiating a contract with Seltrust to conduct pilot plant tests and a full scale feasibility study of establishing a plant with a capacity of 3,500 tons of cathode copper per year. It is estimated that the study will cost $1,000,000.

Other exploration work in the Feinan area has indicated a deposit containing 1,500,000 tons of manganese ore grading 38 percent Mn and 1.4 percent Cu. Very provisional estimates of possible reserves in the area set a figure of 5,000,000 tons of ore. In order to upgrade the ore and to solve the problem of separating copper from manganese, bulk samples of the Wadi Dana ore have been subjected to a number of physical and chemical studies.

It has been found that the recovery of both manganese and copper is possible using either leaching or reduction. However, they are so intimately associated that very specialized and expensive techniques would be required to produce separate marketable products.

Jordan's phosphate-bearing belt covers about 60 percent of the area of the country. It extends, near the surface, throughout all the area covered by Upper Cretaceous sediments, from Ras Naqb in the south to the Yarmouk River in the north. The tricalcium phosphate content ranges from 60 to 73 percent.

The Jordan Phosphate Mining Company (JPMC) operates three open pit mines. Total production in 1981 was 4,243,653 tons and sales amounted to 3,523,216 tons.

Sofremines has signed a contract to study the massive Shadiya phosphate deposits. Here the total reserves are 1,073,070,000,000 tons, consisting of 790,000,000,000 tons proven reserves, 133,000,000,000 tons indicated reserves, and 150,000,000,000 tons inferred. The study is to include mining, beneficiation, transportation, marketing, and infrastructure. The target is to reach a production level of 3,000,000 tons by 1990 increasing to 10,000,000 tons per year by the year 2000.

The Arab Potash Company is proceeding on target with its development of the Dead Sea potash project. Production is to start in September 1982 at an output of 240,000 tons of potash per year. This will increase steadily to reach a rate of 1,200,000 tons a year by 1985-86.

Jordanian mineral production in metric tons

Commodity	1979	1980	1981
Phosphate	2,880,000	3,951,000	4,243,653
Clays	18,044	25,147	20,786
Gypsum	6,313	65,997	53,054
Dolomite	6,141	343	—
Glass sand	577	416	1,800
Marble	2,884	8,675	4,490
Industrial sand	675	2,520	—
Natural sand	261,770	371,519	226,600

1.0 metric ton = 1.1 short tons. 1.0 short ton = 0.0907 metric ton.

MALAYSIA

Exports of refined tin fell 5.7 percent, or 4,071 metric tons, to 66,870 tons last year. The shipments included tin derived from both Malaysian as well as imported concentrates. Europe continued to be the leading buyer, taking 31,723 tons, with Japan in second place, taking 17,756 tons, and the United States buying 10,462 tons.

Production fell 2.3 percent, or 1,466 tons, to 59,938 tons. Output was at the highest level in the last quarter of the year, with a total of 15,455 tons mined. Gravel pump mining continued to produce the bulk of tin concentrates, accounting for 44,180 tons, or 55.6 percent of the total. Dredging accounted for 29 percent, producing 23,017 tons. Dulang washing brought in 4,209 tons, while open pit mines produced 3,431 tons. The remainder of the concentrates were produced from underground mines and retreatment. The number of active miing units fell drastically from 852 in 1980 to

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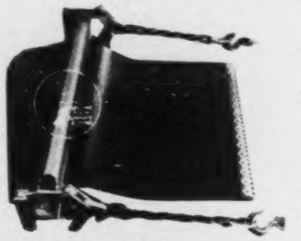

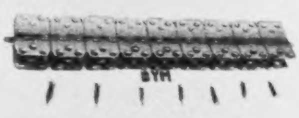

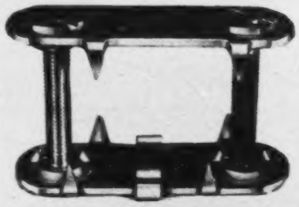

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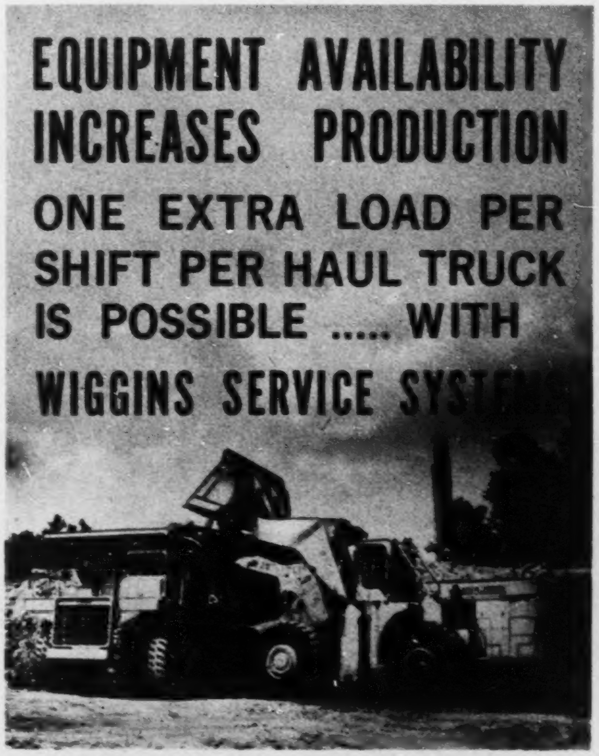

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710 last year. Of these, 593 were gravel pump mines, 60 dredges, 35 open pit mines, and 22 other types of mine.

During the second half of last year the tin market was in a very confused state, due to massive, mystery buying of tin, involving about a quarter of the world's annual consumption, that kept the price at an artificially high level. There was also grave concern in Malaysia about the United States General Service Administration's (GSA) plans to release 30,000 tons of tin onto the market during the following years, and about the United States' refusal to join the new (Sixth) International Tin Agreement.

Malaysian production of minerals and ores in metric tons

Commodity	1979	1980	1981
Tin-in-concentrates	62,995	61,404	59,938
Bauxite	385,520	920,356	700,866
Iron ore	350,498	371,186	532,455
Kaolin	32,934	46,324	
Wolfram	100	68	67
Gold[1]	197	156	180
Barite	1,401	—	19,365
Columbite	40	33	22
Copper concentrates[2]	104,697	114,222	120,327
Ilmenite[3]	199,819	189,121	172,757
Monazite[3]	542	347	300
Zircon[3]	1,271	552	1,307
Scheelite[3]	3	—	—
Antimony	N.A.	N.A	318

1. Kilograms. 2. The copper concentrates contained 28,642 tons of copper, 2,175 kilograms of gold, and 14,708 kilograms of silver in 1981. 3. Exports. 1.0 short ton = 0.0907 metric ton. 1.0 metric ton = 1.10 short tons.

Late in the year, the world's largest and most influential tin mining company, MMC (1976) Berhad was formed by the merger of Malaysian Tin Dredging (M) Berhad and Malaysia Mining Corporation Berhad. This company now operates 38 dredges within the country and is actively prospecting for new mineral resources. MMC produced 8,820 tons of tin concentrates in the financial year ending June 30, 1981.

MMC has agreed with the Selangor state mining organization to form a joint venture company, Kuala Langat Mining, to develop the largest tin project in the country, Kuala Langat (Landang Brooklands). The deposit contains more than 200,000 tons of tin.

In Johore, MMC's prospecting has identified an economic alluvial tin deposit within a 500-acre area that is expected to be developed in the near future. In Negeri Sembilan, several potential tin-bearing areas have been identified, and exploration programs are being set up. In association with Perak SEDC, MMC is involved with the Timah Dermawan project, a large alluvial tin deposit. Mining of this property is expected to begin this year.

Two copper-molybdenum belts that also contain gold and silver have been found in Kelantan and Pahang by the Geological Survey Department. Uranium graces are also to be found in the samples taken from the Kelantan belt. Detailed prospecting is being carried out in Sok, Ulu Kelantan, to evaluate the uranium potential.

Toward the end of 1981 the discovery of a major copper deposit in Kelantan was reported, some 300 kilometers (186 miles) north of Kuala Lumpur. Detailed information is still not available, but the deposit is widely reported to be of significant size by world standards.

NEPAL

Exploration of a copper prospect at Chirling Khola in the Bhojpur district of eastern Nepal is underway. Detailed prospecting is also being carried out in Dandeldhura district for tin, tungsten, and other metals. Encouraging results

Nepalese production or ores and minerals in metric tons

Commodity	1979	1980	1981[2]
Beryl[2]	130	121	51
Clay	4,000	17,788	15,788
Garnet[1]	45,273	44,148	23,500
Limestone	32,427	43,716	22,516
Talc	893	741	11
Tourmaline[1]	13	5	5
Lignite	2,795	4,466	2,735.66

1. Kilograms. 2. Figures up to June only. 1.0 short ton = 0.907 metric ton. 1.0 = metric ton = 1.10 short tons.

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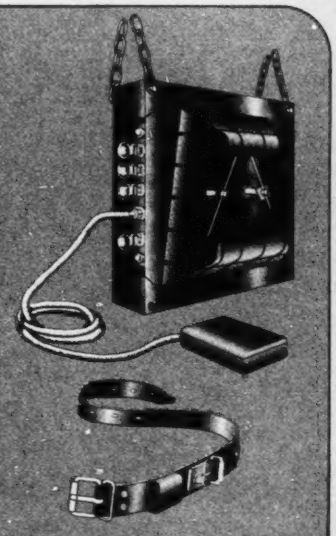

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have been achieved in prospecting for phosphorite in the Doti and Baitadi districts of far west Nepal. Mapping is being carried out for prospecting of radioactive minerals in the Siwalik range. Airborne magnetic surveys have already delineated some favorable areas.

Hyderabad Asbestos Company, in conjunction with Golder Moffit Associates, is likely to bring the Ganesh Himal lead-zinc prospect into production. Output of lead-zinc concentrate at a rate of 25,000 metric tons per year is expected to start in late 1983.

OMAN

The $150,000,000 Sohar copper mining and smelting project is proceeding on target. Partially refined copper will be ready for export by the middle of this year. The mine, operated by Oman Mining Company, is on the northern coast, about 270 kilometers (168 miles) from Muscat.

The smelter will process 1,500,000 metric tons of concentrate annually, to produce 20,000 tons of copper. Originally, this was to be for export, but in February 1981, construction of a $15,000,000 electrolytic refinery was approved. This opens the possibility of local manufacture of copper products. The refinery will also produce byproduct silver. Reserves at the mine are conservatively estimated to last for 12 to 15 years.

PAKISTAN

A total of $9,600,000 was invested in mineral developments during 1981, a decline of about 7 percent over the previous year.

In its continuing efforts to make headway with the oft-delayed Saindak copper project (412,000,000 tons averaging 0.366 percent Cu) in the Chagai district, Baluchistan, the Resource Development Corporation (RDC) has had little success because of difficulties in finalizing arrangements for foreign participation. This would ensure the availability of technology and a $250,000,000 foreign exchange component, out of a $400,000,000 investment needed for the project.

Pakistan production of ores and minerals in metric tons

Commodity	1979 to 80	1980 to 81
Chromite	4,000	3,000
Gypsum	362,000	368,000
Limestone	2,798,000	3,464,000
Magnesite	1,635	397
Rock Salt	495,000	514,000
Marble	92,000	114,000
Silica sand	104,000	84,000
Coal	1,504,000	1,597,000
Barite	18,799	21,208
Feldspar	12,056	11,071
Sulphur	294	403
Ochers	267	445
Fire clay	56,503	60,485
Antimony	—	5
Fullers earth	27,210	21,285
Bentonite	1,461	893
Cement	3,343,000	N.A.
Bauxite	2,044	1,754
Dolomite	15,760	24,244
China clay	15,333	40,022
Manganese	168	84

Source: Statistical Division, Government of Pakistan, Karachi.

Since April 1979, when the project was given the go ahead, several offers have been received from foreign companies. However, negotiations have not reached a stage where a deal could be finalized. Uzinexportimport of Romania had initially considered the possibility of supplying the entire foreign exchange component, but later offered to supply machinery and equipment worth some $120,000,000, which would only partially meet the project's needs.

A consortium of three companies—SNC International (Canada), Cofral RTB-BOR (Yugoslavia) and Emmisa (France)—would, however, make a formal commitment to meet the entire foreign exchange requirements after completing a new, $6,000,000 detailed study of the potential of these deposits. The cost of the study is being met by the group against guarantees from Pakistan. The Geological Survey of Pakistan (GSP) made some major mineral discoveries in Baluchistan Province. Copper deposits were discovered at Koh-i-Dalil and Dash-i-Kain in the Chagai district and at Ann-Dhoro and Saap-Dhoro in the Lasbela district. The GSP, with United Nations Development Program (UNDP) assistance, has started an evaluation of these deposits. Molybdenum was discovered at Darbanchah, about 96 kilometers (60 miles) northwest of Nokkundi, also in the Chagai district.

Chromite production, which was 41,000 tons in 1941, fell to a mere 3,000 tons in fiscal 1981. The machinery and equipment of the Muslimbagh chromite mines, Zhob valley, Baluchistan, has become out-dated and plans are underway to replace it. Under a one-year trade agreement signed in October 1981, Pakistan will export large quantities of chromite to North Korea.

Several varieties of precious stones are found in Pakistan, including rubies, spinel, aquamarine, beryl, topaz, garnet, diopside, pink kunzite, quartz, sapphire, tourmaline, agate, zircon, jade, torquoise, moonstone and lapis lazuli.

Some of the finest emeralds of the world are found in the valley of Swat. The Gemstone Corporation of Pakistan (GCP) produced 62,000 carats of emeralds from the Swat mines over the last three years. Itis extracting 1,700 carats from the Swat emerald mines. The emerald deposits are stretched over a distance of 64 kilometers (40 miles) from Mingora to Malam Jabba.

The government is considering a proposal to let Sarhad Development Authority form joint ventures with international mining companies to develop a mining industry in the North West Frontier Province. PMDC is presently studying market conditions in the Gulf and African countries.

SAUDI ARABIA

Following extensive drilling, development prospecting, and metallurgical testing, a 400-metric ton per day mine has been proposed by Gold Fields Mahd adh Dhahab Ltd. for the Mahd adh Dhahab gold deposit. The mine would have an output of 3,500 kilograms (112,525 ounces) of bullion per year. Metallurgical tests have shown that 95 percent of the gold and 93 percent of the silver can be recovered by froth flotation followed by cyanidation.

In the Shakhtaliyah-Al Muwayh area, a drilling program has revealed two promising zones. An order of magnitude estimate gives 3,000,000 tons at 5.5 grams of gold per ton in zone I.

The Baid al Jimalah tungsten prospect in the northeast of the Arabian Shield has been extensively examined. The surface expression exceeds 2,000 meters in length, and the width varies from a few to about 200 meters.

Extensive lateritic bauxite reserves exist near Az Zabirah, 400 kilometers northwest of Ar Riyad. Sampling and drilling undertaken to date has delineated two areas of potentially economic bauxite within which the inferred ore averages 58.5 percent alumina and amounts to 143,000,000 tons. Beneficiation testwork is underway.

Detailed drilling of the Nuqrah prospect has shown the deposit to consist of two high-grade copper-lead-zinc masses separated along strike by about 70 meters (230 feet) of low-grade mineralization. The deposit also contains significant gold and silver mineralization, and metallurgical tests undertaken by the partners, Petromin and Granges International Mining, have shown that concentrates can be obtained with reasonable recoveries of both base and precious metals.

In the Khnaiguiyah/Al Amar area much work has been carried out on base metal prospects. Four main ore bodies have been identified at Khnaiguiyah and the current total reserves estimate is 12,000,000 tons at 5.26 percent Zn and 0.34 percent Cu with significant but unquantified Ag. Six satellite prospects in the immediate vicinity have been targeted for detailed prospecting. In all, 14 base metal prospects in the Khnaiguiyah-Al Amar area have been examined and only three have been rejected as unpromising.

Diamond drilling has continued at the site of the Jabal Guyan ancient workings within the 1,100-square kilometer Greater Al Masane license area. Results from 14 holes over a strike length of 900 meters indicate an average grade of approximately 10 grams (0.32 ounce) of gold per ton over a true width of 1.5 meters.

The detailed examination of the Wadi Sawawin iron ore deposits has been completed showing proved, indicated, and inferred reserves totalling 330,000,000 tons of taconite ore grading 42 percent Fe, amenable to open pit mining.

Testwork continues on the metalliferous mud deposit in the Red Sea. It covers an area of 65 square kilometers and varies in thickness from 2 to 30 meter. Reserves have been estimated at 1,700,000 tons of zinc, 400,000 tons of copper, and some 5,000,000 kilograms (160,750,000 ounces) of silver.

The Wadi Sawawin iron ore, Az Zabirah bauxite, Baid al Jimalah tungsten, and Mahd Adh Dhahab gold prospects are considered to have particular potential for the Kingdom. In the longer term, the reconnaissance geological mapping of the Arabian Shield has great significance. The intention is to complete mapping of the entire Shield, along the Red sea coast. Completion of the project is expected in 1985.

SOUTH KOREA

The production record here in 1981 showed a similar trend to the previous year. Iron ore production continued to decline and most of the mining sector has experienced difficulties in operation due to lower prices.

Mineral exploration activities are being carried out mainly by the government-operating agencies KIER and KMPC. Some small-scale lead, zinc, and molybdenum deposits were found and uranium exploration also continued. KMPC conducted two longhole drillings onto the newly detected, stockwork type, molybdenum ore body beneath Sangdong mine.

Korea has metallurgical capacities greater than its ore production capacities and imports large quantities from abroad every year. Copper production is almost totally dependant on imports, and iron, more than 90 percent.

Though well-known for its tungsten production and exports, Korea has recently experienced difficulties owing to the price decrease on the international market. Sangdong mine, operated by Korea Tungsten Mining Company Ltd., accounts for over 90 percent of domestic production every year (in 1981 production share was 93 percent). It includes a 2,500 ton-a-day flotation plant.

Representative of the lead and zinc mines in Korea would be the first and second Younhwa mines, operated by Youngpoong Mining Company Ltd., which accounted for 59 percent of lead and 84 percent of zinc output in 1981. They are also having difficulties due to the increased cost of deep mining and lower grades.

Youngpoong Mining Company also operates Boopyoung silver mine. It produced 41 tons of silver in 1981, 10 tons more than in 1980. Korea produced about 100 tons of silver, 30 tons more than 1980. However, 57 percent of the silver production was as by-products from copper smelting.

South Korean smelter/refinery capacities in metric tons

Name of works	Product	Capacity
Pohang	Steel	8,500,000
Koryo	Zinc	65,000
Sukpo	Zinc	31,000
Janghang	Electrolytic copper	50,000
	Lead	10,000
Onsan	Electrolytic copper	80,000

South Korean mineral production in metric tons

Commodity	1979	1980	1981
Iron ore	357,800	346,000	332,500
Copper ore	474	372	453
Lead	11,100	11,530	13,630
Zinc	62,480	56,790	56,200
Tungsten	3,421	3,451	3,457
Molybdenum	314	500	780
Gold[1]	749	1,282	1,346
Silver[1]	70,848	71,301	100,218

1. Kilograms. 1.0 metric ton = 1.1 short tons. 1.0 short ton = 0.907 metric ton.

SRI LANKA

Sri Lanka faces a new era of development in her agricultural and industrial sectors. One of the most ambitious programs ever seen on the island, the Mahaweli project, is the inter-basinal diversion of rivers. From the beginning the probable inundation of mineral resources was stressed. Already action has been taken to extract known resources before they become unapproachable and unmineable. In this context the idea of mechanized gemming has been given fair publicity. It has now been introduced to the country and is functional.

Such trends may have future effects. Already at the mechanized mining site the presence of alluvial gold has been detected and has attracted much attention. Gems in Sri Lanka largely occur in the alluvial gravels. Semi-precious and precious stones other than emeralds and diamonds occur in a wide variety and abundance in these gravels. For some time gems have been the principal foreign exchange earner of mineral commodities. This year exports recorded by the State Gem Corporation amounted to $10,722,000.

During the current year 168 tons of scrap mica had been produced and exported. Production of graphite by the state sector was 4,490 tons (graphite is the only deep mined mineral in Sri Lanka) exported, worth $4,650,000.

TAIWAN

Underground mining at the Chinkuashih gold-copper mine, the largest metal mine in Taiwan, was completely suspended in 1981 due to the lower copper and gold prices. With the cessation of underground mining, cement copper production also came to an end in 1981. Only open pit gold mining in the auriferous outcrops still continues partly for the recovery of silicified country rocks used as flux in the refinery. The new copper smelter and refinery, with a capacity of 50,000 metric tons per year, was in full operation in 1981. The old refinery at the mine is scheduled to shut down in 1982. Copper mining in Tungshan was also closed down due to the low copper price.

Serpentinite in the metamorphic basement of eastern Taiwan was extensively mined in 1981 as a substitute for dolomite, which is used as a flux in the steel industry. Serpentinite production in 1981 reached 118,175 metric tons. Dolomite production decreased appreciably in 1981, down almost 25 percent on the 1980 output.

A heavy mineral sands processing plant will soon be established in southern Taiwan to extract monazite, ilmenite, magnetite and other heavy minerals from the sands. The main purpose is to recover rare elements in the monazite. In addition to locally produced heavy sand, a considerable amount of concentrate will be imported from Australia.

Taiwan production of minerals in metric tons

Commodity	1979	1980	1981
Coal	2,719,751	2,573,530	2,445,782
Gold	443	413	1,763
Silver[1]	2,655	2,957	6,683
Copper, electrolytic	15,305	19,303	53,230
Sulphur	8,946	8,099	9,849
Pyrite	536	150	20
Talc	11,194	9,911	24,774
Asbestos	2,957	683	2,317
Gypsum	4,394	8,170	6,039
Limestone	13,126,267	12,822,025	13,220,570
Marble	1,976,347	2,838,726	3,269,094
Dolomite	530,183	488,725	359,405

1. Kilograms. 1.0 short ton = 0.907 metric ton. 1.0 metric ton = 1.10 short tons.

THAILAND

Although tin production in 1981 fell by 7 percent from that of 1981, the tin royalty collected in 1981 still represented some 89 percent of the total mineral royalties received by the government of Thailand. The export of tin metal and other minerals, valued at $515,480,000, retained its place as Thailand's third largest foreign exchange earner. Over 32,000 metric tons of tin metal was legally exported in 1981. Reliable reports indicate that the total export may exceed the official figure by 15 percent.

The off-shore tin mining industry

continued to be plagued by the official tolerance of mining boats, which roamed freely along the coastal deposits in Pangnga province. The Off-shore Mining Organization's (OMO) first dredge commenced operations during the year. The bucket chain dredge was designed by MTE of the Netherlands and built in Singapore. Billiton Thailand Ltd. was the most successful contractor engaged by OMO in the mining of its coastal property in Pangnga province.

Sethasub Karnrae Company Ltd., which had terminated its contract with OMO, suffered financially when its dredge was not allowed to mine in Associated Mines (Thailand) Ltd.'s mining lease at Karon Bay in Phuket, after a protest against off-shore mining on environmental grounds.

Thailand production of concentrates, ores, and metals in metric tons

Commodity	1979	1980	1981
Cassiterite	46,384	45,980	42,968
Tin Slag	N.A.	12,356	2,232
Wolframite	3,108	2,661	1,832
Scheelite	435	473	516
Lead ore	20,515	24,847	40,667
Metallurgical fluorite	177,730	172,784	157,311
Chemical fluorite	82,122	60,108	55,181
Antimony	6,905	6,862	2,820
Manganese ore	35,324	54,310	10,917
Lignite	1,256,467	1,426,566	1,686,044
Barite	378,654	305,057	307,046

1.0 short ton = 0.907 metric ton. 1.0 metric ton = 1.10 short tons. N.A. Not available.

Aokam Thai Ltd. completed its third year of operations with the slightly reduced production of 1,347 tons of cassiterite. Tongkah Harbour Ltd., the Thai successor of the pioneering first sea dredging company in the world, obtained only one mining lease, which restricted its operations during the year.

The production of lead in 1981 increased 63 percent over 1980 output. The large increase was contributed by the Song Toh mine in the province of Kanchanaburi, the largest underground mine in Thailand. Mining by room and pillar methods began early in 1980. The operating company, Kemco, is 51-percent owned by Bhol & Sons and 49 percent by Metallgesellschaft.

Belgium and Thailand signed an agreement during the year for the establishment of a joint venture to build a $130,000,000 electrolytic zinc smelting plant at Tak in northern Thailand. Under the agreement, the Padaeng Industry Company was incorporated with Thai government agencies and commercial banks holding 70 percent of the shares. Belgian companies, Vielle Montagne and Mechin, hold 28 percent and the Belgian Corporation for International Investment, 2 percent. The Belgian government has provided export credit guarantees and interest subsidies and has granted an interest-free soft loan to the Thai government. The smelter is expected to be completed in 1985 with annual production of 60,000 tons of zinc ingots.

The zinc project has had a troublesome history of over the past 10 years, with previous foreign partners of several nationalities witdrawing for various reasons.

After 10 years preliminary exploration for potash in the north-eastern provinces of Udon Thani, Sakon Nakorn, Kon Kaen, and Maha Sarakam, the government has granted concession rights for exploration and development of the deposits to three Thai-American joint venture companies. These are a consortium of Duval/CRA with Siam Cement, Amax Exporation in partnership with Siam Cement, and a joint venture between Agrico & Thai Central Chemical Company.

According to the Board of Investment, the Duval/CRA/Siam Cement joint venture plans to invest more than $521,740,000, in the exploration and development of potash deposits over a 3,500-square-kilometer area in Kon Kaen and Maha Sarakam provinces. The Amax/Siam Cement venture plans to survey and mine an area of 144 square kilometers in Sakon Nakorn province with an investment of $434,780,000. The third participant in the potash in-

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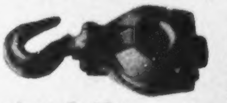

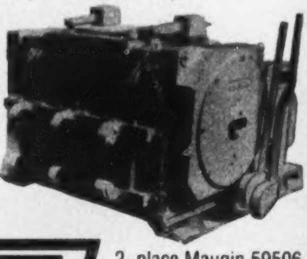

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dustry, Agrico/TCC, estimates its investment at $495,650,000 to drill and mine an area of 2,333 square kilometers in Udon Thani province.

The cement industry increased its production with subsequent increased outputs of gypsum, limestone and shale. Thailand was ready to export cement by the fourth quarter of 1981.

TURKEY

Production and sales from the metal mining sector declined in 1981 due to the recession in the Western World.

Boron remained the major export in the minerals field but sales declined by about 8 percent. Etibank is currently reorganizing the private mines under the nationalization law. The large open pit mine at Bigadiç has started to produce. The concentrator is also operating. A new boric acid plant at Bandirma, with a capacity of 100,000 tons per year, is almost on stream.

Chromite mining has declined due to the recession in the steel industry and due to competition from South Africa and Zimbabwe, both of which can sell at lower prices. Turkey could only sell to the eastern countries under special agreements. The level of ferrochrome production, however, was satisfactory. The Elazig plant is to be expanded to raise production from 35,000 to 50,000 tons per year.

Aluminum and alumina production remained at the same level, with some sales to the Soviet Union. Due to power shortages, metal production was limited.

Lead and zinc production also declined. Some ores were exported for smelting and pure metals were imported. Magnesia, magnesite ore production and exports continued about the same. However, in the future, a magnesia brick plant will be built, incorporating Soviet technology.

Turkey, although a copper country, could not increase copper production and had to import concentrate for the Samsun smelter. The copper refineries had to operate below full capacity due to a shortage of blister copper.

Some increase in barite production was accomplished and ground barite exports amounted to $17,300,000. Some 23,000 tons of a new product, strontium salt, were exported at a value of $2,400,000.

UNITED ARAB EMIRATES

Hunting Geology and Geophysics is conducting the third stage of a mineral survey in the country. The first two stages, carried out by the same company, resulted in the discovery of significant amounts of copper, chromite, and other minerals in the northern Emirates. This third stage will concentrate on ore reserve and grade estimation, and should be completed in 1983.

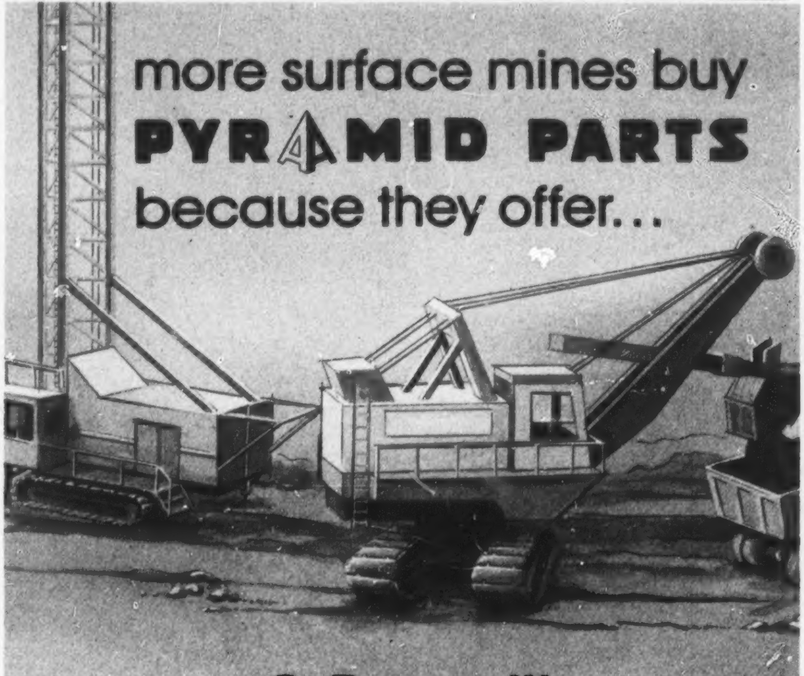
A major delegation from Pakistan visited the country late in 1981. The aim was to increase Pakistani exports of minerals, particularly gypsum, rock salt, talc, silica sand, china clay, and chromite, to the area. The Emirates imported just 155,320 kilograms (342,282 pounds) of gypsum in 1980, compared with 1,869,392 kilograms (4,122,009 pounds) in 1979.

YEMEN

Last year Bureau de Recherches Gèologiques et Minières signed a further prospecting contract with the state minerals agency, Yominco. The new contract follows a general search, already completed, in which some 15 mineral occurrences, including copper, lead, zinc, and silver, were discovered. Core drilling is expected to be undertaken at some of the sites following more detailed surveys.

Two core samples have been taken at a copper deposit at Al-Baidha, near the southern border. Prospecting has also revealed an old silver mine at Majma, west of Marib. The mine has promising lead, zinc, and silver occurrences.

Elsewhere in Yemen, Geomin is investigating a promising low-grade copper prospect at Al-Hamoura.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WORLDWIDE SURVEY
AUSTRALIA

By Leo A. Lyons
Australasian Editor

The table of mine production tells its own story—output of all mineral commodities down. Coupled with increased costs and generally reduced prices, the picture was gloomy indeed. No improvement is in sight for 1982; in fact, without some dramatic upturn, which is not anticipated, the year will be even worse than 1981. Coal production fortunately increased considerably but failed to reach its full potential as a result of labor disputes and shipping problems, often related. Despite increases in wages and other charges, at least some inflationary factors are modified by price increases when contracts are renegotiated. The same may be said for iron ore but here there was sharply reduced tonnage. In the case of metals such as copper, lead, zinc, gold, and nickel, where sales are largely related to open market influences, the situation is serious and, in some cases, calamitous.

QUEENSLAND

Saleable coal production increased by 21.5 percent from 28,500,000 metric tons in 1980 to 34,700,000 in 1981. Some 27,700,000 tons, mostly coking, were exported (19,500,000 to Japan). Mines controlled by Utah Development Company produced about 18,000,000 tons but mines controlled by other groups will steadily come on stream during the next few years. The German Creek mine has begun exporting and will work toward an eventual production of 4,000,000 tons per year. It has put a new township on the map: Middlemount. Blair Athol steaming coal deposit, after years of limited production, has sold 72,000,000 tons over a 15-year period from 1984. The Tarong project will supply 65,000,000 tons to a local power station over a 16-year period commencing next year. About 90 percent of Queensland coal is at present mined from opencut (strip mining) and it will be 10 to 20 years before this ratio alters greatly.

MIM Holdings continues its copper and lead-zinc-silver operations at Mount Isa and Townsville. The group is 44 percent owned by Asarco and holds 21 percent of that group. MIM is making a big push into coal by expanding its Collinsville output to 2,000,000 tons per year. Its wholly-owned Newlands mine is budgeting for 4,000,000 tons per year while the Oaky Creek development (at presnet 79 percent MIM) will produce 3,000,000 tons per year. MIM is involved with 40 percent interest with Seltrust Holdings in the Agnew Nickel and Teutonic Bore mines in Western Australia.

Queensland Phosphate Ltd. (now owned by Western Mining Corporation Ltd.) has resumed production of direct shipping grade rock at Duchess as the beginning of a rehabilitation program. Extensive trials of the rock were made at the Kooragang Island (near Newcastle, New South Wales) works of Australian Fertilizers Ltd. AFL continues to prospect and test phosphate deposits in Queensland, Northern Territory and Western Australia, partly in association with other companies such as International Minerals and Chemicals Corporation of the United States.

Queensland at last has its own integrated aluminum industry despite disappointments due to the general downturn in aluminum demand. Boyne Smelters Ltd., a consortium led by Comalco Ltd., began production in February. Some 40,000 metric tons of metal will be cast this year, rising to 206,000 tons per year—mostly for export—by 1984 and to 412,000 tons by 1990. Alcon Australia Ltd. cancelled plans for a smelter of 300,000 tons per year capacity at Bundaberg.

Only three months after commencing an $A200,000,000 expansion program to lift capacity to 2,330,000 tons per year. Queensland Alumina Ltd., after breaking its own production records, closed one of three digestion units because of reduced Al_2O_3 demand. The Weipa bauxite mine felt the effects of the world aluminum downturn, shipments of beneficiated bauxite declining by 15.6 percent compared with 1980 to 8,000,000 tons.

NEW SOUTH WALES

Coal production and exports were plagued by strikes and transport problems—more so than in Queensland. Ships have been lined up outside the ports of Newcastle and Kembla for weeks and even months. Australia's reputation as a relaible supplier has suffered accordingly. As in other areas of mineral production—much of which is still in the "potential" category—governments and labor unions have endeavoured to harvest the fruits of a resources boom before the boom came to fruition. Nevertheless, 1981 coal output was up from 50,700,000 tons to 60,700,000, of which 76 percent came from underground mines. Exports were 24,100,000 tons: 15,500,000 going to Japan.

In the aluminum industry, the euphoria of two years ago has evaporated. The state government than competed with other states to attract smelters by offering electric power packages at price considered almost suicidal by some analysts. In the event, without demand from new aluminum smelters, the state-owned electricity supply authority has barely been able to meet demands—and then only by appeals for voluntary rationing by consumers.

Alcan Australia Ltd. is deferring completion of a third potline of 45,000 tons per year capacity which would have expanded annual metal output to some 135,000 tons. The much discussed Lochinvar project in the Hunter Valley, not far by Australian standards from Alcan's plant at Kurri Kurri, has been abandoned. This was to have been a joint venture by Amax and Australia's BHP group. BHP is suffering due to reduced steel sales and import competition: "the Big Australian" is still desirous of diversifying into aluminum and is involved in the Worsley alumina project in Western

Production of selected minerals, ores, and metals in metric tons in Australia

Commodity	1979	1980	1981
Bauxite	27,583,000	27,179,000	25,541,000
Coal:			
Black	93,043,000	93,664,000	111,700,000
Brown	32,597,740	32,894,000	33,000,000
Copper in mine products	237,610	243,540	223,352
Iron ore and concentrate	91,717,000	95,534,000	84,781,000
Lead in mine products	421,158	397,481	390,113
Zinc in mine products	529,157	495,312	504,210
Gold in mine products (ounces)	654,857	600,077	618,058
Silver in mine products (ounces)	29,355,375	27,048,687	25,505,280
Manganese ore	1,724,000	1,999,000	1,418,000
Nickel in mine products	69,709	74,323	74,000
Tin in mine products	12,571	11,588	12,083
Tungsten (WO_3 units)	402,610	450,840	419,000
Ilmenite concentrate	1,181,010	1,384,563	1,317,284
Rutile concentrates	274,533	311,744	229,251
Zircon concentrates	444,975	491,547	425,064
Sulphur content (of pyrite and metallic concentrates)	394,680	350,476	356,460
Portland cement	5,243,000	5,497,000	6,087,000
Phosphate rock	7,557	7,6,621	4,937

1981 data are preliminary. Source: Bureau of Mineral Resources, Geology and Geophysics, Canberra A.C.T.

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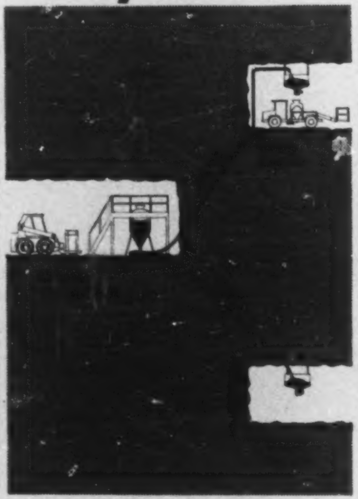

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Australia.

The bright news in aluminum is that the Tomago smelter, also in the Hunter Valley area, appears to be on schedule. Initial capacity will be 110,000 tons per year by 1984 and may be doubled by 1986. CSR Ltd., which has a 51 percent share has moved far from its initial development only in sugar being deeply committed to energy and mineral developments. Pechiney has a 39 percent stake in the Tomage smelter.

Although the citizens of Broken Hill, the "Silver City", fear that their town will become a shell within 20 years, revision of ore reserves in accordance with guidelines of the Australian Institute of Mining and Metallurgy has added considerably to life expectations of the Conzinc Riotinto of Australia (CRA) controlled mines: Zinc Corporation Ltd. and New Broken Hill consolidated at the southern end of the lode. What is ore is inevitably related to special factors at Broken Hill in addition to the now accepted norm of an inflationary spiral; that is, the substantial "lead bonus" paid to employees and high royalties exacted by the government. At 7.7 percent Pb, 11.5 percent Zn, and 2.1 ounces Ag per ton (high grades by most standards), ore expectancy is 52,800,000 tons; at Pb-plus-Zn of 7 to 10 percent reserves may increase by 10,000,000 tons. However, at 3 to 7 percent Pb-plus-Zn a further 40,000,000 tons may be available. Expectations for North Broken Hill Ltd. similarly become more favorable. If in the future, managements and unions can work out realistic agreements, the Broken Hill area will be producing, in part from ore bodies yet to be defined, well into the next century.

EZ Industries Ltd. is advertising for personnel for the Elura lead-zinc mine north of Cobar. The main shaft will be completed this year. A decline shaft has reached 2,000 meters. The town of Cobar, where Cobar Mines Pty. Ltd. hopes to expand production, is enjoying a construction boom as much of the Elura mines workforce will be housed there. Cobar Mines produces copper, lead, and zinc concentrates from the CSA mines but can only reach its full potential by developing deep and relatively rich copper lodes some 10 kilometers to the south when metal prices justify expansion of output. CRA Ltd. may be expected to do this as soon as conditions appear appropriate now that it controls the Cobar field.

Mining and concentration problems at the complex copper-lead-zinc Woodlawn mine, near Canberra, have been partly overcome. Mining is now at the rate of 15,000,000 tons per year of which waste to ore ratio is 7 to 1. Concentrates have increased in grade. The mine is an equal partnership between CRA, Phelps Dodge Corporation, and St. Joe Lead Company and is managed by CRA.

Peko Wallsend's porphyry copper deposit, said to encompass a possible 1,000,000,000 tons around 5 percent with sections up to 1 percent is unlikely to see early development. Peko has been exploring in an area near Parkes for several years. Similarly, CSR Ltd.'s Mount Pleasant moly project is not likely to be quickly in a development stage.

VICTORIA

Brown coal production by the State Electricity Commission from its mines east of Melbourne was almost static at 33,000,000 tons. A possible 10 percent increase is foreseen during 1982.

CRA Ltd. astonished many observers when it acquired a 50 percent interest in the Japanese Showa Denko group for 25,000,000 yen ($A100,000,000). CRA holds 45 percent of Comalco Ltd. which now has obvious opportunities for future metal sales. This represents much the largest Australian investment in Japan. Most investment deals are by Japanese companies securing access to Australian raw materials and trading opportunities. Comalco's share of primary aluminum smelting capacity now stands at about 200,000 tons per year and may increase to about 325,000 tons per year within two years as a result of the Boyne smelter (Queensland) and expansion at Bluff (New Zealand).

Western Mining Corporation Ltd. continues to prospect the Wilga and Currawong Zn-Pb deposits near Benambra in the north east of Victoria. Near Stawell in the central west a decline tunnel to investigate gold occurrences is almost half way to completion. WMC is involved with Central Norseman Gold Corporation (which it effectively controls) in the Stawell venture.

Alcoa of Australia has increased capacity at its Point Henry (Geelong) aluminum smelter from 101,000 tons per year to 165,000 tons per year. The outlook for the new Portland smelter is clouded. The first section of this ambitious 535,000 tons per year project is still likely to come on stream late in 1983 at a rate of 120,000 tons per year. Meanwhile, Alcoa has reported that it is seeking purchasers for the smelter, not merely partners.

TASMANIA

Comalco's Bell Bay smelter produced 114,420 tons of aluminum. The plant has been modernized and this resulted in a small capacity increase to 117,000 tons per year (Kaiser Aluminum holds 45 percent of Comalco with CRA).

The Renison tin mine, now part of the reorganized Renison Goldfields Consolidated Ltd. with headquarters in Sydney, suffered from labor problems, like most other mines and manufacturing groups in Australia. Nevertheless, tons treated were up slightly, tin output was up despite slightly lower grade and recovery.

Deliveries from the Que River mine to EZ Industries concentrator at Rosebery are rising towards 200,000 tons per year. Production from EZ's own mines is around 150,000 tons per year of zinc concentrate and 25,000 tons of each lead and copper concentrates. Zinc concentrate is treated in the company's refinery at Risdon near Hobart.

SOUTH AUSTRALIA

Additional ore reserves at Broken Hill removed any doubts about the future of the Broken Hill Associated Smelters (CRA controlled) at Port Pirie. This 200,000 to 220,000 ton per year lead smelter and zinc fuming plant is expected to instal a Kivcet unit for future lead smelting. Negotiations with Russian authorities have been drawn out.

Western Mining Corporation Ltd.'s brown coal discovery near Kingston is shaping well. It extends over an area of 35 kilometers by 7 kilometers with a thickness of 8 meters under 40 meters of overburden. The coal is suitable for a future power station.

Western Mining/BP's Olympic Dam project is bedevilled by political problems. The Labor party and Democrats, voting together in the state Parliament, have blocked passage of a bill which would have committed the government to a A$50,000,000 expenditure on infrastructure. The joint venturers would then spend $A50,000,000 on a feasibility study. On June 18, the resignation of a prominent Labor politician made it likely that a resubmitted bill would proceed. Both Labor and Democrats hold an anti—uranium stance and the vast Olympic Dam copper deposit has sufficient associated uranium to qualify it as the greatest reserve of U_3O_8 in a continent that already holds a large portion of the world's high grade reserves.

WESTERN AUSTRALIA

Seltrust/MIM's Teutonic Bore mine, 320 kilometers north of Kalgoorlie and 80 kilometers south of the partnership's Agnew Nickel mine, commenced production in June. Ore mined to date has averaged 3 percent Cu, 11.5 percent Zn, and 6.5 grams Ag per ton. Early technical problems due to oxidized ore have been overcome. At present an open pit operations underground will commence in 1984. At Agnew Mining Company, production of nickel continued to suffer from dilution and other problems but concentrate grade has recently been increased to acceptable levels. The property is not expected to become profitable until the deeper, disseminated ore bodies are reached and nickel prices improve. A 14 feet diameter shaft is being drilled to

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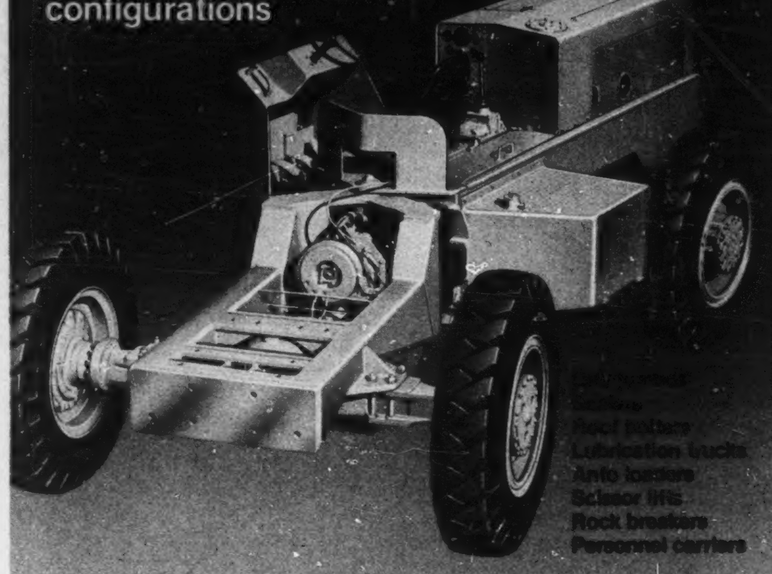

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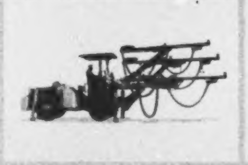

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Gold producers are reeling from the unexpected steep and long decline in the metal price. North Kalgurli and the rehabilitated Hill 50 at Mount Magnet are suffering losses and the partners of Kalgoolie Mining Association, Homestake, Poseidon, and G.M. of Kalgoorlie having spent more than $30,000,000 on new plant and development, are seeing expected profits vanish. Central Norseman Gold Corporation has mined some higher grade ore; grade at Kalgoorlie Associates mines has been below average and will improve.

Alcoa of Australia has cut Al_2O_3 production at Kwinana and Pinjarra refineries to 85 percent of capacity. The Worsley project will provide alumina that some partners do not want in the present climate. The often discussed smelter, in which Reynolds was to be involved, seems destined for indefinite deferrment. Mitchell Plateau Bauxite (MPBC), 100 percent owned by CRA, has a 52.5 percent share in the Mitchell Plateau bauxite/alumina project. Alcoa of Australia, Billiton Aluminium, Sumitomo Aluminium Smelting, Sumitomo Corporation, and Marubeni Corporation are also involved. A feasibility study is in progress but development appears unlikely in the forseeable future. MPBC also has a 67.5 percent interest in the cape Bougainvill bauxite deposit, 80 kilometers north of the Mitchell Plateau and a 100 percent interest in a bauxite deposit at Muchea, northeast of Perth.

Mineral sands producers Allied Eneabba and Westralian Sands had a satisfactory 1981. Zircon content of the sands is higher on the wester side of Australia than in the east. Prices for this commodity have remained firm. In conjunction with Westralian, CRA has announced an 18-month feasibility study of a plant to produce titanium sponge. CRA endorses federal government philosophy that processing of Australian raw materials should, where possible, take place in Australia. Western Mining Corporation was interested in a possible titanium plant of about 10,000 tons per year capacity a few years ago but plans did not mature.

WMC's Yeelirrie uranium project received a setback when Esso, holding 15 percent interest with various options, decided to withdraw. Although this is expected to be a low cost operation, U_3O_8 prices have fallen from $4.00 per pound to about $20.00 on the spot market since planning began.

Although tungsten and Mo are in the doldrums, some interest still attaches to the Mt. Mulgine prospect where reserves of 37,000,000 tons at 19 percent WO_3 with Mo 4 percent in lower zones of deposit. ANZECO, a part subsidiary of Union Carbide, has become involved with the project, located 85 kilometers northeast of Perenjori.

Iron ore production was down at the Pilbara mines. Labor problems have been at a maximum, although wages and conditions are good. Some price escalations have been arranged with Japanese buyers, notably by the Robe River group whose pellet plant is in mothballs and only fines are being shipped. Since existing mines are well below optimum operating levels even the one new proposed development appears unlikely for some time to come.

CRA Ltd. and its Ashton Joint Venture associates, Malaysia Mining Corporation (29 percent) and Northern Mining Corporation (5 percent), have made significant progress in the development of the Argyle diamond prospect in the Kimberly region of Western Australia. A wholly-owned CRA subsidiary, Argyle Diamond Mines Pty. Ltd., has been incorporated to be the manager and operator of behalf of the joint venturers. Limited commercial production on alluvial deposits adjacent to the kimberlite pipe AK-1 is expected to commence during the second half of 1982, subject to state approval.

Cumulative totals for Argyle alluvial deposits show recovery of 79,393 carats from 21,331 metric tons of Upper Smoke Creek treated material and 8,116 carats from 22,071 tons recovered from Lower Smoke Creek. Intensive evaluation of the principal resource AK-1 continued through 1981, with extensive surface bulk sampling, structural and large diameter core drilling. Work commenced last November on a definitive feasibility study that will result in a recommendation to the joint venturers for a decision to proceed with a final design and construction of a large scale commercial plant.

A second alluvial deposit on Limestone Creek to the east of AK-1 was defined and sampled during the second half of 1981. Some 14,399 carats were recovered from 8,714 tons of material treated. Preliminary calculations indicate reserves contained in Upper Limestone Creek to be equivalent to the Upper Smoke Creek deposit.

NORTHERN TERRITORY

The "NT" is now a state of the commonwealth and is showing drive in advancing the interests of the mineral industry, an industry upon which most future development depends. The government is even canvassing possibilities for a uranium enrichment plant at Darwin, pointing to the fact that Australia's high grade reserves are in "the Territory"

The Ranger uranium mine is well into production: output is at a rate in excess of the planned plant capacity of 3,000 tons of yellowcake per year. There were early problems in shipping due to hostility by maritime/wharfside unions although the mining unions produces cheerfully in disagreement with an official Council of Trade Unions anti-uranium policy.

Peko Wallsend Investments Ltd. (H.O. Sydney) was forced to close its Tennant Creek flash smelter for the second time due to technical problems and uneconomic operation.

The Gecko gold mine was also closed and gold recoveries were less than expected at the Warrego mine. Peko is looking to Ranger in which (like EZ Industries) it has a 30.8 percent share. The Ranger mine is operated by Energy Resources of Australia Ltd. in which foreign groups also participate. (Peko has also reduced output at is scheelite mine, King Island Scheelite, on King Island, Tasmania.)

Shipments of iron ore and pellets by Australian mining companies and mines

Mine	1976	1977	1978	1979	1980	1981
			BROKEN HILL PROPRIETARY COMPANY LTD.[1]			
Cockatoo	2,881,200	8,500,000	730,000	1,174,000	779,000	84,000
Koolan			1,590,000	2,28[illegible]	1,517,000	1,950,000
Koolanobbing	2,028,600		1,110,000	1,386,000	1,695,000	830,000
Iron Monarch	4,008,200		2,470,000	864,000	748,000	1,073,000
Iron Prince, Iron Baron				1,821,000	1,789,000	1,073,000
Total	8,198,000	8,500,000	5,900,000	7,526,000	6,528,000	3,937,000
			CLIFFS ROBE RIVER IRON ASSOCIATES[5]			
Pellets	4,217,234	3,741,104	4,210,326	3,394,057	1,046,175	33,823[4]
Fines	8,219,235	9,154,549	8,085,928	9,628,263	11,550,349	12,424,052[4]
Total	12,436,469	12,895,653	12,296,254	13,022,320	14,596,524	12,424,052[4]
			HAMMERSLEY IRON PTY. LTD.[3]			
Mount Tom Price	22,405,000[4]	21,141,000[4]	29,445,000[4]	19,855,000	—	—
Paraburdoo	—	12,778,000[4]	13,726,000[4]	12,939,000[4]	—	—
Total	35,183,000	34,867,000[4]	29,445,000[4]	32,824,000	38,950,000	29,100,000
			MOUNT GOLDSWORTHY IRON ORE JOINT VENTURE[2]			
	7,318,704	6,5[illegible]7,225	6,600,000	6,960,018	5,370,356	5,546,655[4]
			MT. NEWMAN MINING CO. PTY. LTD.[2]			
Mt. Newman	30,252,197	28,540,145	31,265,800	30,579,800	27,679,154[4]	27,753,423[4]
			SAVAGE RIVER MINES LTD.[2]			
Savage River pellets	2,[illegible]70,199	2,180,850	2,027,823	2,158,730	2,273,679	2,215,000

1. Metric tons. 2. Long tons. 3. Includes pellets. 4. Gross tons. 5. Wet metric tons.

WORLDWIDE SURVEY
CANADA

After a strong 1979, and a steady, promising 1980 in the face of general economic malaise, the Canadian mineral industry finally slumped in 1981. It was, and still is, in one of the worst recessions since the Great Depression in the 1930's. Total value of mine, smelter, and refinery output in 1981 was up 3.9 percent from 1980 to C$33,100,000,000 ($25,800,000,000), but this increase was far below the 22.2 and 28.7 percent increases of the two years previous to 1981. In fact, metal mining output value fell about 3.1 percent to C$9,700,000,000 ($7,600,000,000). Copper revenues were down 14.5 percent; nickel, 5.5 percent; gold, 24.4 percent; and silver, 41.2 percent.

Reduced demand, depressed prices and stagnation in the housing and automotive industries, the biggest consumers of everything from aluminum to zinc, made it a discouraging year for most metals. Copper output increased by less than 1 percent, and the Canadian producer price for full-plate cathode ranged from C$1.05 ($0.82) a pound at the beginning of the year to C$0.94 ($0.73) at the end, significantly lower than the C$1.18 ($0.92) a pound in 1980.

The nickel industry, plagued by slumping steel markets, saw output reduced 16 percent in 1981. Posted nickel prices were not representative of actual sales, as producers discounted in an attempt to move inventories. Lead hardly fared better, with output up less than 10 percent and value down 2 percent.

Despite the continuing erosion of the price of gold, several new gold mines were being developed throughout in 1981, and exploration for gold was also

Tons of ore mined and waste stripped at selected open pit mines in Canada

		1979		1980		1981	
Company	**Mine**	**Ore Mined**	**Waste Stripped**	**Ore Mined**	**Waste Stripped**	**Ore Mined**	**Waste Stripped**
Advocate Mines	Baie Verte	2,613,000	13,903,000	1,896,000	12,104,000	N.A.	N.A.
Afton Mines	Kamloops Operation	3,000,000	20,000,000	3,390,000	19,410,000	3,110,000	18,220,000
Asbestos Corp. Ltd.	British Canadian	4,922,000	11,948,300	3,557,000	11,140,800	2,615,223	8,228,007
	King Beaver	2,935,400	5,552,800	2,307,700	4,344,200	1,968,160	3,646,171
Bethlehem Copper Corp.	Iona Jersey Pit Extension	7,699,756	8,640,756	7,505,636	15,146,052	7,908,412	15,281,384
Brenda Mines Ltd.	Brenda Mine	10,004,260	9,092,600	10,060,000	10,048,500	11,242,700	11,734,000
Caland Ore Company, Ltd.	Steep Rock Lake Operations	1,852,000	5,285,000	—	—	—	—
Cassiar Asbestos Co. Ltd.	Cassiar Mine	1,083,444	12,681,808[12]	1,109,330	7,212,541	1,710,432	4,781,494
Cleveland-Cliffs Iron Co.	Adams Mine[3]	4,842,186	2,505,310	5,054,604	3,839,181	5,054,000	3,840,000
	Sherman Mine[3]	3,781,801	6,188,984	4,214,401	8,005,981	4,214,000	3,066,000
Cyprus Anvil Mining Co.	Anvil Mine	2,822,000[2]	7,166,327[1]	2,825,000	8,376,663	N.A.	N.A.
Gibraltar Mines Ltd.	Gibraltar Mine	12,426,700[10]	13,919,000[10]	38,510,000	14,801,000	27,141,000	
Highmont Operating Corp.	Highmont Mine	—	—	850,000	7,500,000	9,700,000[9]	9,400,000[9]
Iron Ore Co. of Canada	Carol Project	44,309,788	9,127,155[1]	51,588,261	8,143,674[1]	51,588,261	8,143,674[1]
	Knob Lake Mine	5,430,892	2,929,500[1]	9,562,732	9,039,015	6,793,928	6,241,725
Johns-Manville Canada, Inc.	Jeffrey Mine	9,808,952	24,921,092	—	—	—	—
Lac d'Amiante du Quebec, Ltee.	Black Lake	4,001,937	10,914,209	4,033,132	9,787,589	4,300,000	10,000,000
	National	2,064,727	3,791,098	2,236,275	5,205,327	2,400,000	5,050,000
Lornex Mining Corp.	Logan Lake	17,776,000	N.A.	17,678,000	41,557,000	22,861,000	70,488,000
Mattabi Mines Ltd.	Sturgeon Lake Operations	944,578	957,938	1,042,000	N.A.	922,000	390,000
National Steel Corp. of Canada, Ltd.	Moose Mountain Mine	417,000	286,000	—[7]	—[7]	—[7]	—[7]
Newmont Mines Ltd.	Copper Mountain	—	—	107,000	2,010,000	3,645,000	5,445,000
Similkameen Div.	Ingerbelle	7,605,000	3,725,000	7,289,000	10,566,000	3,926,000	363,000
Noranda Mines Ltd.	Bell Mine	5,491,035	3,688,003	5,525,000	8,631,000	5,985,000	9,302,000
	Boss Mountain	386,450	139,350	274,397	32,250	9,330	833,825
	Granisle Mine	5,185,019	9,251,430	3,518,983	10,172,521	4,155,770	8,346,612
	Mont Copper	5,586,000	7,694,000	9,783,000	N.A.	N.A.	N.A.
	Mont Needle	66,000[4]	—	1,489,000	—	N.A.N.A.	
Pamour Porcupine Mines Ltd.	Timmins Division	293,297	—	202,000	—	N.A.	—
Pine Point Mines Ltd. Cominco Ltd.	Pine Point Operations	3,291,000	11,900,000	3,626,000	13,100,000	3,600,000	21,700,000
Placer Development Ltd.	Endako	5,256,000	4,280,000	11,451,000	13,193,000	10,524,000	11,819,000
Quebec Cartier Mining Co.	Mount Wright	34,537,000[2]	21,048,000[2]	33,278,000	33,278,000	30,157,000	29,700,000
Sherritt Gordon Mines Ltd.	Ruttan Pit	—	—	1,898,415[10]	847,915[10]	—	—
Steep Rock Iron Mines Ltd.	Hogarth Mine	950,000[6]	8,000,000[6]	—[5]	—[5]	—[5]	—[5]
Syncrude Canada Ltd.	Mildred Lake Operations[2]	50,400,000	362,000,000	73,800,000	47,700,000	N.A.	N.A.
Utah Mines Ltd.	Island Copper Mine	15,695,000	41,105,000	15,300,000	44,700,000	15,500,000	41,900,000
Wabush Mines	Scully Mine	5,581,889	17,651,227	6,395,496	4,893,510	N.A.	N.A.

1. Cubic yards. 2. Metric tons. 3. Long tons. 4. Closed six months due to strike. 5. Closed September, 1979. 6. Strike from Jan. 1 to Feb. 6. 7. Shut down indefinitely May 1. 8. Reflects strike in early January. 9. Figure includes 2,700,000 low grade to stockpile. 10. Completed December 1980. All figures in short tons unless otherwise specified. 1.0 short ton = 0.907 metric ton = 0.893 long ton. 1 metric ton = 1.10 short tons. 1 long ton = 1.12 short tons. N.A. Not Available.

widespread. The Carolin Mines Ltd. gold mine in the Cascade Mountains of British Columbia was the most notable example. After proceeding steadily toward start-up in 1981, the first doré bullion was poured on February 3, 1982. The mine achieved its design capacity of 1,500 tons of ore per day early on, and plans are now to increase this rate to 2,400 tons per day.

The Lupin gold mine of Echo Bay Mines Limited maintained a steady course toward development. Located in completely isolated country in the Northwest Territories, this mine should be producing 1,000 tons of ore daily sometime in 1982. Reserves are estimated at 27,000,000 tons of ore averaging 0.38 ounce gold per ton.

British Columbia has another new gold mine near Stewart. Scottie Gold Mines plans to be producing gold at the rate of 4,500 ounces per month, as well as 2,800 ounces of silver monthly. There were 200 tons of ore being milled daily at last report. Reserves in 1981 were listed at 226,000 tons averaging 0.65 ounce gold per ton.

In the east, the Orofino gold property in Ontario looks promising. Estimated mineralization in early 1981 totalled 896,000 tons averaging 0.21 ounce gold per ton.

Another far northern property is owned by Procan Exploration Company (controlled by the Hunt brothers of the United States) through its Cadillac Exploration Ltd. subsidiary. Located near Dawson City, Yukon Territory, this deposit would be a placer operation, producing as much as 55,000 ounces of gold per year.

Silver also remains popular in Canada despite its sagging value. Trident Resources Inc. started milling at its Atlin-Ruffner, British Columbia silver mine in 1981, processing about 60 tons of ore per day. Milling will be steadily increased to 100 tons per day as the mine develops.

Cadillac is planning to mine 1,000 tons of ore per day at Prairie Creek, in

Canadian mineral production in kilograms

Commodity	1979	1980	1981[3]
METALLIC MINERALS			
Bismuth	136,733	149,000	123,000
Cadmium	1,209,459	1,033,000	1,274,000
Calcium	455,713	531,000	566,000
Cobalt	1,639,624	2,118,000	1,816,000
Columbium (Cb_2O_5)	2,512,667	2,463,000	2,740,000
Copper	636,382,578	716,363,000	718,082,000
Gold[1]	51,142,359	50,620,000	49,500,000
Iron Ore[2]	59,617,286	49,068,000	49,844,000
Lead	310,745,203	251,627,000	272,928,000
Magnesium	9,014,999	9,252,000	8,775,000
Molybdenum	11,174,586	11,889,000	14,134,000
Nickel	126,481,900	184,802,000	155,175,000
Platinum Group Metals	6,156,716	12,776,000	12,057,000
Selenium	217,759	279,000	290,000
Silver	1,146,908	1,070,000	1,203,000
Tellerium	42,433	15,000	20,000
Tin	336,757	243,000	248,000
Tungsten (WO_3)	3,254,067	4,007,000	1,736,000
Uranium (U)	6,530,418	6,739,000	7,746,000
Zinc[2]	1,099,926	883,697	995,049
INDUSTRIAL MINERALS AND COAL			
Asbestos[2]	1,492,719	1,323,000	1,113,000
Cement[2]	11,765,248	10,274,000	10,368,000
Coal[2]	33,200,000	36,688,000	39,250,000
Gypsum[2]	8,098,166	7,336,000	7,800,000
Potash (K_2O)[2]	7,074,388	7,201,000	6,815,000
Nepheline Syenite[2]	605,699	600,000	606,000
Pyrite[2]	31,032	32,000	11,000
Sulphur, elemental[2]	6,314,144	7,656,000	8,320,000

Source: Mineral Policy Sector, Department of Energy, Mines and Resources, Ottawa.

1. Grams. 2. Metric tons. 3. Preliminary. 1.0 metric ton = 1.10 short tons. 0.0326 x grams = troy ounces.

Tons of ore mined from selected underground mines in Canada

Company	Mines	1979	1980	1981
Agnew Lakes Mine Ltd.		448,000	—[8]	—[8]
Algoma Steel Corp. Ltd.	George W. MacLeod Mine	2,670,000	2,529,000	N.A.
Allan Potash Mines	Allan Operations	3,288,000	N.A	1,103,000[10]
Asarco, Inc.	Buchans Unit	125,000	83,000	76,000
Bell Asbestos Mines Ltd.	Bell Mine	1,058,430	955,960	1,210,000
Brunswick Mining and Smelting Corp. Ltd.	#12	2,965,175	1,979,500	3,532,891
	#6	258,888	110,743	24,531
Camflo Mines Ltd.	Camflo Mine	471,701	462,952	413,000
Campbell Red Lake Mines Ltd.	Red Lake Mines	300,000	304,000	369,500
Cominco Ltd.	Con Mine	216,530	212,000	194,000
	Sullivan Mine	2,257,232	2,087,000	2,436,000
	Vade Mine[1]	2,467,000	1,009,000	2,944,511
Canada Tungsten Mining Corp. Ltd.	Tungsten	271,551	344,501	N.A.
Craigmont Mines Ltd.	Merritt Operations	2,102,000	2,105,000	2,151,000
Dankoe Mines Ltd.	Horn Silver Mine	N.A.	23,851	N.A
Denison Mines Ltd.	Elliott Lake Operations	2,577,010	2,440,020	N.A.
Dome Mines Ltd.		664,000	678,000557,200[6]	
Falconbridge Copper Ltd.	Opemiska Div.	1,052,490	1,059,000	936,555[9]
Falconbridge Nickel Mines Ltd.	East	124,926	240,259	234,471
	Falconbridge	647,716	620,476	484,108
	Fecunis North	—[3]	—	N.A.
	Fraser Mine[1]	9,227[3]	13,188	33,104
	Lockerby	39,769[3]	393,981	516,420
	Onaping	N.A.	199,186	95,950
	Strathcona	1,851,603	1,776,441	1,575,391
Giant Yellowknife Mines	Yellowknife	323,048	227,240	227,240
Hudson Bay Mining and Smelting Co., Ltd.	Anderson Lake Mine	65,148	144,376	162,823
	Centenial Mine	193,907	139,133	197,141
	Chisel-Ghost Lake	236,398	242,412	236,401
	Flin Flon Mine	619,663	665,530	634,701
	Osborne Lake Mine	188,937	182,186	197,799
	Stall Lake Mine	272,352	265,733	253,011
	Westarm Mine	175,870	173,055	171,789
	White Lake Mine	129,506	62,944	79,730
International Minerals & Chemical Corp.	K1-K2, Saskatchewan	10,800,000	11,424,000	8,565,000
Kerr Addison Mines Ltd.	Kerr Addison	193,000	215,000	271,666
	Mogul of Ireland	673,000	619,000	609,986
Lamaque Mining Co., Ltd.	Main Mine	334,748	289,644	437,520
Newfoundland Zinc Mines Ltd.	L. Zone	576,804	572,143	540,793
Noranda Mines Ltd.	Boss	—	258,857	465,229
	Central Canada Potash	3,428,000	3,752,000	3,406,000
	Geco Division	1,624,325	1,497,288	1,466,000
	Mattagami Lake	948,310	915,146	961,035
	Mont Needle	675,000	489,000	N.A.
	Norita Mine	358,698	329,273	289,512
	Orchan Mine	128,892	95,528	76,023
	Radiore #2	29,543	124,319	124,319
Pamour Porcupine Mines Ltd.	1 Division	1,738,219	618,231	1,758,000
	3 Division		94,772	
	Ross Division		204,140	
	Schumacher Division		514,370	
Potash Corp. of Saskatchewan Mining Ltd.	Lanigan Division	2,097,467	2,335,421	2,250,000
Rio Algom Ltd.	Quirke Mine	2,348,000	2,340,000	2,454,990
	Panel	N.A.	N.A.	1,139,895
Sherritt Gordon Mines Ltd.	Fox	851,535	864,224	808,587
	Ruttan	384,806	876,629	1,584,903
Tantalum Mining Corp. of Canada, Ltd.	Bernic Lake	180,500	184,000	N.A.
Kidd Creek Mines Ltd.		3,509,156	4,136,939	4,493,400
Union Miniere et Exploration	Umex-Thierry Mine	842,900	937,415	1,100,000
Western Mines Ltd.	Lynx, Myra Mines	294,181	306,712	271,334
Whitehorse Copper Mines Ltd.	Little Chief	935,997	854,300	819,766

1. Metric tons. 2. Short wet tons. 3. Starting or reopening. 4. Closed for 2 months due to strike. 5. U_3O_8. 6. Closed April, 1980. 7. Acquired from Newmont May 31, 1979. 8. Shut down. 9. Closed for 5 weeks due to strike and 2 weeks at Christmas. 10. July 1, 1980—June 30 1981. N.A. Not Available.

the Northwest Territories. Reserves total 1,500,000 tons averaging 5.54 ounces of silver per ton, 11.16 percent lead, 12.7 percent zinc, and 0.44 percent copper. (More details on minerals exploration in Canada may be found on page 59 of this issue.)

Lead and zinc continue to be important. Noranda Mines opened its Mines Gallen open pit operation, located in Quebec, in November. An ultimate mining level of 1,500 tons of ore per day is expected. Reserves are 1,800,000 tons averaging 5.4 percent zinc, 0.75 ounce silver and 0.028 ounce gold per ton.

Cominco Ltd. continued its eight-year, multi-phase expansion and modernization at Trail and Kimberly. More than $200,000,000 had been spent on the zinc electrolytic and melting plant at Trail by mid-1981. Another major portion is a conversion to mechanized mining at the Kimberly Pb-Zn mine.

Canadian non-fuels mineral industry, production 1979 and 1980[1]

	1980	1981[1]	Change
	($1,000,000)		(percent)
Metals	9,697	9,398	-3.1
Nonmetals (excluding coal)	2,532	2,833	11.9
Structural materials	1,668	1,842	10.4
Total	13,897	14,073	1.3

1. Preliminary.

Brunswick Mining and Smelting Corporation Ltd. (BM&S) is also interested in more zinc capacity, announcing in late 1981 plans for a $290,000,000 zinc reduction plant at Belledune, New Brunswick. Start-up is planned for 1984. Capacity will be 100,000 metric tons of zinc metal annually. Cadmium metal and sulphuric acid will be byproducts.

One of the more interesting lead-zinc operations is Cominco Ltd.'s Polaris mine, located Little Cornwallis Island, 900 miles from the North Pole. The facilities were put into place throughout 1981, and by early 1982, the annual capacity rate of 187,000 tons of zinc and 42,000 tons of lead was being reached.

A uranium prospect in northern Saskatchewan was looked at further by Canadian Occidental Petroleum Ltd. and Inco Metals Co. The McClean lake prospect has shown 398,000 tons of reserves averaging 1.8 percent U_3O_8.

Amax of Canada Ltd. extended its option at Logtung Resources Ltd.'s Logjam Creek tungsten-molybdenum deposit in British Columbia. No estimates of reserves have been released.

The continuing poor nickel market forced Inco Metals to reduce operations at Sudbury, Ontario early in 1982. The company also cut back production at its Shebandowan mine and concentrator.

The federal government released a Discussion Paper concerning Canadian minerals policy. Specifically, the paper said that no additional government ownership in the mineral industry is justifiable at this time. Government ownership at the federal level is not now extensive.

The reasoning for this position is that, although prime minister Pierre Trudeau wants to see a Canadianization of all facets of his country's economy, Canadian companies now control most of the major mining companies. However, the situation will be watched closely, to see that such control is maintained.

Recovery from this deep recession hinges on an increased demand for Canadian minerals and minerals products. Since recovery in the United States, Canada's most important trading partner, is expected to be weak, the industry will continue to operate well below its potential. Recovery is not seen before the end of 1982.

Real production of the non-fuel mineral industry is forecast to grow at an average annual rate of 3.0 percent between 1981 and 1991. The first two years of this period have not been rewarding. The next eight will depend heavily on the world economic environment.

This report was prepared by WORLD MINING with assistance from the Minerals and Metals Division, Mineral Policy Sector, Department of Energy, Mines, and Resources, Ottawa, Canada.

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CUBA

Cuba was the world's fourth largest nickel producer in 1981 with an output of 44,600 tons from its Moa Bay and Nicaro lateritic nickel plants. An annual production rate of 110,000 tons is targeted by 1990.

A 33,000-ton per year plant, Las Camariocas, has been planned by the government. It is to be built at Punta Gorda with aid from the Soviet Union. About 75 percent of current nickel output is exported to the Soviet Union and eastern Europe.

DOMINICAN REPUBLIC

There was bad news here in 1981, as Falconbridge Dominicana C. por A. was hit hard by the low nickel prices in 1981. An electric furnace was shut down in June, and the plant was scheduled to be placed on care and maintenance status on January 11, 1982.

Falconbridge Dominicana plans to resume production when the nickel market recovers. Although nickel shipments rose from 36,491,000 pounds in 1980 to a total of 41,180,000 pounds in 1981, an increase of almost 13 percent, Falcon bridge still suffered a net loss totalling $28,059,000 during the year.

At the end of 1981, total proven and probable reserves delineated at the Falconbridge ore deposits were estimated at 63,800,000 tons grading 1.64 percent nickel.

Production at the Pueblo Viejo mine, which is the largest gold mine in the western hemisphere, totalled 412,992 ounces of gold and 2,061,816 ounces of silver in 1981. The mine is owned by the Dominican government and managed by Amax Inc.

HAITI

Reynolds Haitian Mines Inc., the only bauxite company in Haiti, produced 485,000 long dry tons of bauxite ore in 1981. The wholly-owned subsidiary of Reynolds Metals Company has almost depleted reserves, and plans to end operations in 1982.

JAMAICA

Production at most bauxite companies slowed in 1981 and further cuts were planned for 1982. A decline in demand for bauxite foreseen for 1982 will be partially alleviated by the United States' government plan to buy 1,600,000 tons for the U. S. National Defense Stockpile from Jamaica during 1982.

The hoped-for expansion of the domestic bauxite industry will not take place in the near future. Alcoa Minerals of Jamaica's (Jamalco) expansion project at the 550,000-ton per year Clarendon refinery was cut from 650,000 tons to 325,000 tons. Three Norwegian companies that were to participate in the project withdrew.

Considering that Jamalco cut production twice in 1981, it is likely that the expansion project will be further delayed. The government has urged the expansion but Alcoa is waiting for the right financial incentives to be offered. Jamalco is a joint venture between Aluminum Company of America (94 percent) and the Jamaican government (6 percent).

Both Alcan Jamaica Company and Alumina Partners of Jamaica (Alpart) reduced bauxite purchases. Alcan is a subsidiary of the Canadian Company, Alcan Aluminium Ltd. (93 percent) and the government (7 percent). Alpart is owned by Kaiser Aluminum and Chemical Corporation (36.5 percent), Reynolds Metals Company, (36.5 percent) and Anaconda Company (27 percent).

Bauxite and alumina production and shipments from Jamaica in wet long tons

Year	Bauxite exported	Bauxite converted into alumina	Total bauxite produced	Alumina exported[1]
1966	7,028,479	1,898,763	8,927,242	791,151
1967	7,142,422	1,978,879	9,121,301	824,533
1968	6,212,053	2,178,763	8,390,816	907,818
1969	7,601,534	2,731,373	10,332,907	1,138,072
1970	7,575,486	4,244,590	11,820,076	1,689,221
1971	7,589,775	4,653,816	12,243,591	1,783,125
1972	7,048,952	5,292,080	12,341,032	2,102,055
1973	7,273,579	6,112,089	13,385,668	2,377,951
1974	7,873,493	7,212,769	15,086,260	2,760,973
1975	5,482,426	5,991,967	11,338,056	2,337,379
1976	6,283,725	3,938,275	10,220,000	1,622,485
1977	6,255,060	4,958,133	11,253,152	2,000,378
1978	6,346,184	5,204,845	11,735,000	2,108,182
1979	6,500,000	5,000,000	11,570,000	2,070,000
1980	6,100,000	6,000,000	12,148,000	2,390,000
1981	5,294,000	6,312,000	11,606,000	2,550,000

1. Dry long tons. 1.0 long ton = 1.120 short tons. 1.0 short ton = 0.893 long ton.

The United States and Jamaica signed a tax treaty that will allow American bauxite mining, alumina, and aluminum producing companies to receive foreign tax credits on income earned in Jamaica. The treaty was to go into effect January 1, 1982.

PUERTO RICO

The United States Bureau of Mines and the Mineral Resources Development Corporation of Puerto Rico (Codremi) signed a memorandum of understanding for the Bureau to review geological, engineering, and financial data on mining proposals submitted to Codremi by the United States companies, Amax Inc. and Kennecott Corporation. The proposals are for the development of the Utrado, Adjuntas, and Lares copper deposits in western Puerto Rico.

These deposits contain a total estimated 250,000,000 tons of 0.7 percent copper.

The value of nonfuel mineral production in Puerto Rico dropped from $211,000,000 in 1980 to $195,815,000 in 1981. The 7 percent decline was due to a slowdown in the construction industry, which uses most of Puerto Rico's mineral output.

TRINIDAD TOBAGO

No action was taken on the proposed construction of a 180,000-ton per year aluminum smelter, but a decision on this is expected to be made in 1982. The government is considering making National Steel Corporation and Southwire Company, both United States-based companies, joint venture partners in the project. The estimated cost of the project has risen to $700,000,000.

VIRGIN ISLANDS

Martin Marietta Corporation completed an expansion to 700,000 tons per year at its St. Croix alumina smelter in 1981. A plant conversion from oil to coal is scheduled for 1982.

Total 1981 production was 579,000 tons of alumina and 24,000 tons of aluminum. Martin Marietta exports some 165,000 tons of alumina annually to Norway. Most of the bauxite for alumina production is imported from Boke, Guinea, and Surinam.

AUSTRIA

The Austrian mining industry was only partially able to maintain the good level of mineral production of 1980. Production of the important commodities, brown coal and lead-zinc ore, increased 6.85 and 14.85 percent, respectively, during 1981. Targeted, successful exploration has assured further coal reserves. Since 1980 investments for developing known brown coal deposits have been increased.

At Bleiberger Bergwerks-Union AG (BBU) tailings have been retreated since 1980. Purchased ore to fully supply the Arnoldstein zinc smelter with raw material increased costs. The production of 4 tons of Germanium was of scientific importance.

At the Schlaining antimony ore mine production increased 7.4 percent; however, because of decreasing grade, production of antimony concentrate decreased 8.6 percent. Some 95 percent of production was exported. Export of chemical products (synthetic material additives) by BBU also increased.

Iron ore mining at the Steirischen mine was cut back by 4.7 percent, pig iron production decreased slightly in 1981, but crude steel production increased 6.9 percent. Wolfram ore mine production reached almost 460,000 tons in 1980 but declined by 22.3 percent in 1981.

Scheelite was mined; the ore concentrating plant in Felbertal prepares concentrates for the wolfram plant in Bergla. Austria became a tungsten exporter in 1981. In addition, production of anhydrite increased 1.2 percent, dolomite 10.8 percent, and volcanic breccia 1.2 percent.

The salt works at Steinkogl, Hallein, and Bad-Aussee have increased their salt production since 1978 by 7.8 percent; in 1981, this increase was 12.8 percent.

Gypsum production decreased by 4.9 percent and graphite by 35.1 percent. At two of the kaolin mines production declined by 7.5 percent; apart from pure kaolin, quartz sand was also mined. Because of the declining demand for magnesite, production from the five magnesite mines decreased by 160,000 tons, or 12.1 percent.

The value of mineral and energy products increased 7.85 percent in 1981, rising to $892,000,000. Petroleum and natural gas constituted 48.34 percent of this total, followed by non-metallic minerals at 32.05 percent, metallic ores at 8.42 percent, coal at 6.92 percent, and salt at 4.27 percent.

In 1981 there were 90 active mines in operation in Austria, compared to 95 in 1980, as well as smelting works and exploration companies.

CYPRUS

By G. C. Kronides
Ministry of Commerce & Industry
Nicosia

Prospecting activity, both by government and the private sector, continued at a high level. The Government Geological Survey Department has continued its program of exploration both for the discovery of cupriferous sulphides as well as for non-metallic minerals such as bentonite, clays for ceramics and bricks, limestone, umber and strontium.

In addition to the exploration activities of the Gelogical Survey Department for location of massive sulphide deposits, the United Nations Revolving Fund for Natural Resources Exploration, continued its exploration program.

In 1981 the target areas initially defined by satellite imagery and aerial photography interpretation and then refined on the basis of geological mapping and geochemical sampling, were investigated further by geophysical surveys, (induced polarization, microgravity and magnetics) and drilling. The total number of holes drilled was 28 giving a total of 3,760 meters.

The Hellenic Mining Company continued its prospecting program over its mining leases and prospecting permits using both geophysical and geochemical methods as well as drilling. In all 118 holes were drilled, a total depth of 10,000 meters, at a cost of approximately $72,000.

The Cyprus Asbestos Company Ltd. carried out some drilling on its mining lease to evaluate and quantify the ore reserves. The company's open pit mine is by far the biggest mine in Cyprus and a total of 3,167,000 metric tons of ore was mined. The production of finished products amounted to 24,440 tons of chrysotile asbestos made up of 13,870 tons of long grade and 11,570 tons of short grade.

Cyprus minerals export in long tons

Commodity	1979	1980	1981
Asbestos	38,992	30,446	29,081
Chromium ore and concentrate	12,199	6,700	9,868
Copper concentrate	12,322	825	35,670
Iron pyrite	143,904	89,440	656
Sulphite concentrate containing precious metals	—	579	—

1.0 long ton = 1.2 short tons. 1.0 short ton = 0.893 long ton.

At the close of the year the Hellenic Mining Company operated three mines, a copper mine, a chrome mine, and an iron pyrite mine. The company produced the following mineral products: 470 metric tons cement copper, 514 metric tons of concentrates containing precious metals, 15,866 tons of iron pyrite and 10,381 tons of chrome.

Kampia Mines has not carried out any mining operations but sold a quantity of iron pyrite ore held in stock.

At the end of 1981 the first phase of a sulphuric acid, phosphoric acid and a NPK fertilizer plant belonging to the Hellenic Industries Ltd. was completed and some sulphuric acid was produced. Full production is expected in 1982 and its capacity is scheduled for 180,000 metric tons sulphuric acid, 40,000 metric tons of phosphoric acid and 150,000 metric tons of fertilizer.

CZECHOSLOVAKIA

Mining production, in 1981, remained at approximately the same level as in the preceding year. A minor increase in the output of brown coal and non-metallic minerals was seen, while metallic ore production stayed essentially at the previous year's level or even slightly lower.

The output of copper, lead and zinc

Czechoslovakian production of ores, metals, and minerals in metric tons

Commodity	1979	1980	1981
Iron ore	2,012,000	1,927,000	1,935,000
Steel	14,817,000	15,225,000	15,270,000
Lead, metal	19,020	20,014	21,000
Zinc, metal	1,260	1,881	2,000
Copper, metal	31,336	31,000	30,000
Brown coal gross output	93,731,000	92,529,000	93,096,000
Lignite	3,201,000	3,197,000	3,269,000
Black coal net output	28,463,000	28,201,000	27,512,000
Coke	10,458,000	10,323,000	10,323,000
Cement	10,258,000	10,546,000	10,645,000
Limestone	22,910,000	23,884,000	24,156,000
Lime	2,968,000	3,018,000	3,234,000
Washed kaolin	613,000	660,000	652,000
Gypsum	734,000	757,000	767,000
Calcined magnesite			
for brickmaking	314,000	326,000	331,000
for steelmaking	340,000	339,000	333,000

1.0 short ton = 0.907 metric ton. 1.0 metric ton = 1.10 short tons.

comes mainly from the Zlaté Hory and Horní Benesov stratiform deposits in the Jeseníky Mountains, as well as from the subvolcanic ore deposit at Banská Stiavnica in Slovakia. Copper and mercury are the main byproducts of the siderite-tetrahedrite ores from the Slovak mines of Rudnany, Slovinky and Mária bana. The production of mercury from tetrahedrite in the Rudnany deposit is increasing substantially. Stibnite ores are being mined in the Low Tatras, Dúbrava mine, and in the Little Carpathians, Pezinok mine, in Slovakia.

Polymetallic lead-zinc ores are being mined in lower quantities from the famous historic Kutná Hora deposit and the Staré Ransko deposit. Cassiterite and wolframite continues to be supplied from the Cínovec and Horní Slavkov mines. A tin-tungsten deposit has been discovered in the vicinity of the Cínovec mines.

Positive results from geological exploration are being reported from Slovakia, where mineralization very similar to the porphyry copper type has been found, and from Bohemia, where rich polymetallic ores of stratiform type were discovered. Economic concentrations of gold in the Vltava river valley are being explored.

The discovery of large bentonite deposits was one of the most important new nonmetallic findings. Mining of the traditional Czechoslovak non-metallic minerals, refractory clays, kaolin, graphite, fluorite, glass sand, fire clays, etc. continues and the output is increasing slightly.

More attention has been devoted to the problems of mining hard coal from greater depths in the Ostrava coal basin. Here, geological complications are hindering the work aimed at maintaining or even increasing the output of coking coal.

The energy situation has also led to the opening of big open pits located in the North Bohemian brown coal basins, where unfavorable air pollution influenced mining activities.

Czechoslovakian production of ores, metals, and minerals in metric tons

Commodity	1979	1980	1981
Iron ore	2,012,000	1,927,000	1,935,000
Steel	14,817,000	15,225,000	15,270,000
Lead, metal	19,020	20,014	21,000
Zinc, metal	1,280	1,881	2,000
Copper, metal	31,336	31,000	30,000
Brown coal gross output	93,731,000	92,529,000	93,096,000
Lignite	3,201,000	3,197,000	3,269,000
Black coal net output	28,463,000	28,201,000	27,512,000
Coke	10,458,000	10,323,000	10,323,000
Cement	10,258,000	10,546,000	10,645,000
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Washed kaolin	613,000	660,000	652,000
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Calcined magnesite			
for brickmaking	314,000	326,000	331,000
for steel-making	340,000	339,000	333,000

1.0 short ton = 0.907 metric ton. 1.0 metric ton = 1.10 short tons.

FINLAND

The total ouput of Finnish ore and mineral mines remained unchanged in 1981 at the level of 18,200,000 million tons. The production of metalliferous ores totalled 9,700,000 tons, while minerals production stood at 8,500,000 tons for the year.

Pig iron and steel production figures for Finland in 1981 were, respectively, for Rautaruukki Oy 1,507,365 and 1,626,013 tons; Ovako Oy 457,905 and 678,664; and other producers 36,222 of steel only. A total of 1,965,270 tons of pig iron and 2,340,900 tons of steel.

The list of major developments in Finland in 1981 includes:

- The Geological Survey is exploring a small uranium deposit in Southern Finland.
- Outokumpu and Rautaruukki have combined their prospecting and exploration activities in the northern part of Finland.
- Outokumpu is exploring a high-grade nickel deposit at Enonkoski in Eastern Finland. The exploration will continue underground.
- Imported raw materials required for the metallurgical industry, expressed as a percentage of the annual production requirement were; iron concentrate 60 percent, nickel matte 55 percent, cobalt concentrate 45 percent, zinc concentrate 55 percent and copper concentrate 40 percent.

Finnish mine production in terms of ore milled, minerals and metals recovered, and cement produced in metric tons

Commodity	1979	1980	1981
OUTOKUMPU OY			
Ore mined	5,796,074	5,286,236	5,167,459
Copper concentrate[1]	161,635	144,794	152,568
Pyrite concentrate	320,130	324,500	261,352
Zinc concentrate	105,610	113,885	105,478
Lead concentrate	2,922	2,696	3,623
Nickel concentrate[2]	80,345	91,199	82,105
Chromium concentrate	177,586	186,540	201,949
RAUTARUUKKI OY			
Ore mined	4,076,546	4,294,681	4,117,098
Iron concentrate	773,878	810,006	871,280
Ilmenite concentrate	119,700	159,000	161,500
Pyrite concentrate	7,500	8,150	7,530
P_2O_5 (100 percent)	4,941	5,076	5,557
MYLLYKOSKI OY			
Ore mined	480,878	448,000	482,700
Copper concentrate	14,129	11,638	12,130
Pyrrhotite concentrate	156,129	129,085	142,000
Cobalt-nickel concentrate	6,101	3,869	3,500
Zinc concentrate	3,961	2,748	2,950
Talc concentrate	11,675	27,403	41,447
Nickel concentrate	318	807	1,374
YHTYNEET PAPERITEHTAAT OY SUOMEN TALKKI OY			
Ore quarried	357,697	331,515	338,348
Talc concentrate	155,998	164,126	180,997
Nickel concentrate	3,062	4,256	3,106
OY LOHJA AB			
Feldspar concentrate	57,062	74,089	63,066
Quartz concentrate	206,298	222,974	243,169
Talc ore quarried	230,298	294,490	247,040
Nickel concentrate	3,815	4,205	3,726
KEMIRA OY			
Ore quarried	—	1,951,545	2,402,000
Apatite concentrate	—	131,900	200,927
Calcite concentrate	—	8,300	27,037
LIMESTONE AND CEMENT COMPANIES			
Limestone quarried	4,621,807	5,282,423	4,812,623
Cement produced	1,749,103	1,792,520	1,787,079
Wollastonite concentrate	10,576	8,782	13,090

1. Average Cu-content 1981, 23.3 percent. 2. Average Ni-content 1981, 7.6 percent. 1.0 short ton = 0.907 metric ton. 1.0 metric ton = 1.10 short tons.

FRANCE

French uranium production in 1981 was 2,555 tons from yellowcake produced locally and a further 3,000 tons from concentrate imported mainly from Niger and Gabon.

Iron production rose above the 29,000,000 tons of 1980 to 21,600,000 tons. The Lorraine area produced 20,500,000 tons with a further 1,000,000 tons from the western region. The Pyrenean mines produced less than 100,000 tons. Ore grade averaged 31.4 percent Fe, giving 6,800,000 tons of iron from 21,600,000 tons of ore. The iron ore mines had to limit their production to adapt to the needs of the iron and steel industry.

Pig iron production was 17,300,000 tons (compared to 19,200,000 tons in

French mine, smelter, and refinery production of ores, metals, and minerals in metric tons

Commodity	1979	1980	1981
Coal and brown coal	22,000,000	20,700,000	21,500,000
Iron ore	31,600,000	29,000,000	21,800,000
Pig iron	19,400,000	19,200,000	17,300,000
Steel ingot	23,400,000	23,200,000	21,100,000
Bauxite (average Al_2O_3 grade 55 percent)	1,970,000	1,892,000	1,828,500
Aluminum metal	395,100	432,000	435,580
Magnesium	9,048	9,328	—
Silver	229	248	304
Lead concentrate	39,900	39,200	26,614
Lead, refined metal	219,712	218,831	228,000
Zinc concentrate	68,045	66,500	67,790
Zinc, refined metal	248,977	252,770	257,130
Cadmium	706	789	—
Gold[1]	1,258	1,100	913
Copper, refined metal	45,258	46,460	47,000
Nickel, refined metal	2,258	9,792	10,130
Tungsten, metal content	500	577	744
Uranium, metal content	2,360	2,600	2,555
Potash (K_2O content)	1,921,000	1,891,070	1,831,000
Fluorite (average CaF_2 content 80 percent)	275,000	276,000	304,000
Rock salt, untreated	519,000	301,200	298,000
Salt brine	4,149,280	4,415,300	3,870,000
Salt refined	1,075,100	1,112,700	1,092,000
Talc	302,470	316,100	280,000
Sulphur	1,940,000	1,840,000	1,711,000
Barite	235,000	215,000	190,000

1. Kilograms. 1.0 short ton = 0.907 metric ton. 1.0 metric ton = 1.10 short tons.

eastern region, 6,300,000 tons from the northern region, and 3,800,000 tons from other regions. Steel production attained 21,100,000 tons (23,200,000 tons in 1980) exports were 9,350,000 tons and imports were 7,030,000 otns. Imports of iron ore totalled 16,500,000 tons.

Bauxite production was 1,828,500 tons (compared to 1,892,000 tons in 1980) 1,233,000 were mined by Aluminium Pechiney, 339,000 tons by the Société anonyme des Bauxites et Alumines de Provence and 177,000 tons by Alusuisse France. Aluminum production totalled 435,580 tons slightly up in comparison with 1980 which was 432,000 tons.

Lead and zinc production came form the mines of Saint Salvy (Tarn), Malines (Gard), and Largentière (Ardèche). Lead concentrate production amounted to 26,614 tons containing 19,040 tons of lead. Zinc concentrate production was 67,790 tons containing 37,430 tons of metal. Metallurgical production was 228,000 tons of refined lead and 257,130 tons of zinc ingots and 9,250 tons in powder form.

A total of 190,000 of barite was produced; 2,100 tons came from the Farges mine (Corréze) which was operating for only 3 months in 1981 and is now closed, and 106,000 tons from the Chaillec mine (Indre).

Fluorspar extraction amounted to 304,000 tons of 80 percent CaF_2 equivalent. At the tungsten mine of Salau in Ariège, 299 tons of concentrate containing 255.5 tons of metal and 1,027 tons of semiconcentrate containing 519 tons of metal were produced. The Montbellux mine in Ille and Vilaine produced 5 tons of tungsten concentrates and 5 tons of tin concentrate.

The Salsigne mine (Aude) produced only 913 kilograms (29,353 ounces) of gold due to an in rush of water preceded by some exceptional interruptions at the beginning of 1981. The Société of Bourneix was created in November 1981 by Penarroya (68.75 percent) and Coframines (31.25 percent to exploit the Gros Gallet en Haute Vienne Strata. Estimated annual production will be 500 kilograms (16,075 ounces) of gold and 1,200 kilograms (38,580 ounces) of silver starting form the second quarter of 1982. The Luzenac mine (Ariège) produced 313,000 tons of rock which gave 280,000 tons of powdered talc.

The seventh year inventory of French Mineral Resources, generally confirmed the merits of the methods used. Interest in the mineral provinces is now traditionally confirmed. New exploration targets have been identified; the extension of the sedimentary volcanic mineralization of the Pays de Loire and Nord du Massif central; mineralization of a new type in France (tungsten, molybdenum, lead, zinc, and copper) in the east of the Massif Armoricain and in the Bosges.

Feasibility studies were carried out on two polymetallic layers Cu, Pb, Zn, Ag of Bodennec (Finistère) and Porte aux Moines (Côtes du Nord). Mining was delayed and it was decided to study them more thoroughly.

Research was carried out on the Montredon tungsten project (Tarn) and a tin, tantalum prospect at Echassières (Allier).

GREECE

By **Aristides Barounis**
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Revision of the mining law; incentives for the development of small mines; the rescue, by government, of some mining enterprises from bankruptcy; and the appointment of government supervisors to the administrations of big mining companies are some of the measures which have been taken or will be taken by the new socialist government in its efforts to further develop the Greek mining industry.

The exploration carried out by the state organizations, Institute for Geology (IGME), Power Corporation, and National Petroleum Company concentrated on energy minerals and precious metals, uranium, coal, oil, gold, and silver. Exploration drilling and trial production is underway in the Serres and Sidirokastron areas of eastern Macedonia where some commercial uranium deposits have been proved. In precious metals exploration is concentrated on the ancient Pageon Mountain gold mines operated during the time of Alexander the Great. Results, so far have been very satisfactory.

Larco, the country's only nickel producer, and one of the biggest in the European Economic Community, is in financial difficulties and is expected to be nationalized. Negotiations between the mines and industry ministry and the Bodossakis group, the current owner, are believed to be in the final stage.

Another mining company with severe economic problems is Kirki Mining Ltd., which, until two years ago mined the complex sulphide mines of the Kirki area in Thrace. In these mines a public investment of $91,500,000 in mining works, machinery, treatment installations, and surface facilities remains idle with a danger of becoming obsolete.

Production from the iron ore and manganese mines has mostly ceased because the Halivourgiki blast furnaces of the Eleusis area have stopped operations. Reopening of this, Greece's only major iron production unit, will be difficult because the new government will enforce repairs and environmental protection systems to a total cost of more that $10,000,000. Howver, the EMD manganese production plant of the Skalisititi group, located in the area of the Drama manganese mines, is still operating with an annual capacity of 10,000 metric tons.

Areas of increased mining activity for the year 1981 were the production of marble, perlite, and bentonite. Bauxite and magnesite production remained the same and there was some decrease in the output of complex sulphides. The new government is considering some revision of the mining law, but the initial idea of nationalization of the mineral wealth has now been abandoned.

Some work, in cooperation with Iraq, has gone into the development of a second alumina-aluminum complex to be based on Greek bauxite. However, the plan is not expected to be successful because of Iraq's war problems and the fact that Greece and Iraq do not have the technology necessary for the design and construction of such a project.

Exploration drilling for brown coal is concentrated on the target areas of the Amydeon Florina and Ptolemais neogene lignite basins in which the construction of five new thermoelectric plants by French-Soviet consortium are planned. Lesser drilling programs are underway at other smaller lignite basins.

Greek production of ores, minerals, concentrates, and metals in metric tons

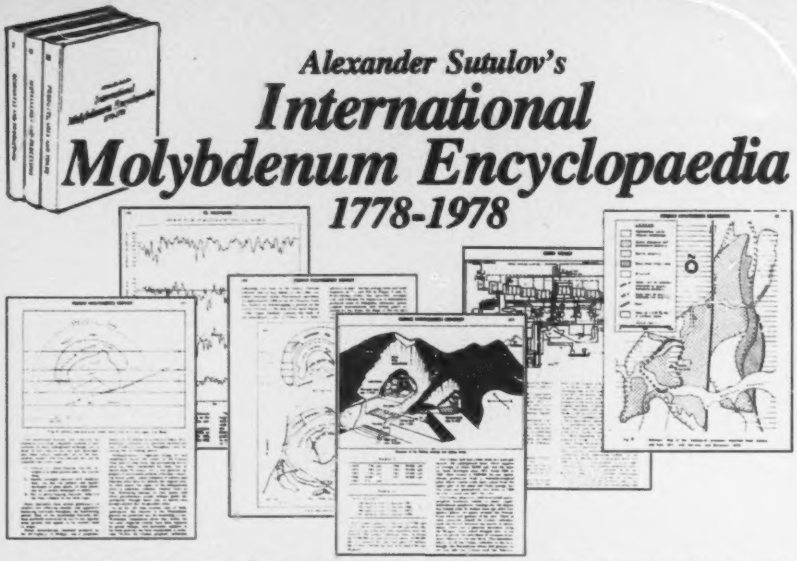
Commodity	1979[1]	1980[1]	1981[1]
Bauxite	3,000,000	3,000,000	3,000,000
Nickeliferous iron ore	2,000,000	2,000,000	1,500,000
Magnesite	400,000	400,000	400,000
Mixed sulphide	750,000	750,000	700,000
Manganese ore	78,000	78,000	60,000
Chromite concentrate	32,000	32,000	30,000
Chromite, mined	75,000	75,000	70,000
Lignite	21,000,000	21,000,000	21,000,000
Gypsum	450,000	450,000	450,000
Silica	25,000	25,000	25,000
Kaolin	65,000	65,000	65,000
Bentonite	350,000	350,000	380,000
Perlite	300,000	300,000	350,000
Aluminum	145,000	145,000	145,000
Alumina	475,000	475,000	475,000
Barite	160,000	160,000	170,000
Lead	17,000	17,000	15,000
Lead concentrates	35,000	35,000	35,000
Magnesite, dead burnt	300,000	300,000	300,000
Nickel, alloy	15,000	15,000	12,000
Pyrite	200,000	200,000	200,000
Zinc concentrate	38,000	38,000	38,000
Fluorite	500	N.A.	N.A.

1. Estimated. N.A. Not available. 1.0 short ton = 0.907 metric ton. 1.0 metric ton = 1.10 short tons.

GREENLAND

The output of the Black Angel Mine, operated by Greenex A/S, amounted to 38,059 metric tons of lead concentrate and 139,823 tons of zinc concentrate. The company continues to identify further ore, and has kept its ore reserves at approximately the same level since operations began in 1973.

A/S Kryolitselskabet Øresund experienced a slight decline in the sales production of refined natural cryolite, obtained from stockpiled crude ore from Ivigtut in South Greenland, as compared to previous years.



Alexander Sutulov's
International
Molybdenum Encyclopaedia
1778-1978

Two hundred years after its discovery, molybdenum is no longer a laboratory curiosity. Twentieth-century technology has taken note of its sophisticated properties and found ways of using them, turning molybdenum into one of the world's most important alloying and energy metals.

Demand has increased 2,500 times in the last 75 years, and is expected to grow still further—into the 21st century—as researchers find new and diversified applications for this versatile metal.

Now available is the world's first comprehensive and systematic source of reference on molybdenum—the INTERNATIONAL MOLYBDENUM ENCYCLOPAEDIA 1778-1978. From the standpoint of 200 years' experience comes this new modern summary and in-depth evaluation, updated to 1978. It puts vital information about molybdenum at your fingertips, in one convenient source.

Primary molybdenum production is detailed in great depth. In addition, extensive coverage of molybdenum by-product recovery from copper porphyries makes this reference equally useful to those involved in the copper and rhenium business.

Volume I: Resources and Production

- The geology of all important ore bodies, mineralogy, geochemistry and evaluation of resources.
- Principal producing and consuming countries; corporations and plants involved in molybdenum production, conversion and alloying.
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At year's end, a 3-year field survey of the coal measures of West Greenland was terminated. No further work has been commissioned, although the final report indicated that large reserves of high volatile bituminous coal in workable seams exist in the sedimentary basin of the Nûgssuaq peninsula at 70° north. Other energy related surveys were not extended beyond 1981.

Prospecting activity has declined somewhat, and no promising finds have been reported.

Greenland mineral production and exports in metric tons

Commodity	1979	1980	1981
Cryolite ore	46,000	47,000	48,000
Cryolite concentrate[1]	21,100	20,700	17,600
Lead concentrate	44,500	43,200	38,000
Zinc concentrate	151,200	140,500	139,800

1. Exported from Denmark. 1.0 short ton = 0.907 metric ton. 1.0 metric ton = 1.10 short tons.

HUNGARY

By **József Molnar**
Engineering Geologist
Budapest

Approximately 3.5 percent of the national income is spent on research and development each year, the majority of which goes for exploration and research into resource utilization. Recent work has concentrated on coal and bauxite deposits. Geological exploration in progress has upgraded the information on proven reserves and discovered further resereves. The country's known reserves are 37 percent coal; 30 percent industrial minerals; 27 percent building materials; 5 percent bauxite, iron, manganese, copper, lead, and zinc; and only 1 percent hydrocarbons.

Bauxite production reached 2,900,000 metric tons in 1981. The new mines of Bitó II and Halimba III have gone into production, the latter supplying one third of the country's output. At Fenyófő, Mt. Bakony, another new mine with an output of 650,000 tons of bauxite has gone on stream. Current known reserves are sufficient for another 30 years, taking into consideration planned consumption increases.

Alumina production totalled 799,000 tons. Because the available indigenous smelting capacity is low, much of the alumina is sent to the Soviet Union for further treatment. As part of the sixth Five-Year Plan a new 100,000-ton aluminum smelter is to be built in Hungary. The Ajka alumina plant and aluminum smelter is now supplying castings for the automobile, machine tool, and electronics industries. Széshfehérvár Light Metal Works produced 143,000 tons of aluminum semi-products.

At Rudabánya, the country's only iron ore mine, mining of limonite and ankerite has practically ceased and extraction is now centered on the more abundant reserves of siderite. The output of siderite in 1981 amounted to 422,000 tons. The country's iron and steel industry also processed imported ores, mainly from the Soviet Union, with coke supplied from overseas. The smelters supplied 2,200,000 tons of pig iron, 3,600,000 tons of crude steel, and 2,800,000 tons of rolled steel. About 70 percent of this production served the home market and the rest was exported. An integrated steel plant being built at Diósgyór is expected to be completed in 1982. It will include an 80-ton arc furnace and a continuously operating steel foundry.

The Urkut manganese ore mines in Transdanubia supplied 120,000 tons of oxide ore and a small amount carbonate ore. The production of this ore is restricted by the fact that there is insufficient smelting capacity and no ferromanganese production. Proved and potential reserves would allow an expansion of output, provided that demand increases.

The Lahóca copper mine at Recsk has been exhausted. Since mining of other, recently discovered deposits at Recsk has not started yet there is currently no copper production. Reserves of the new deposits are estimated to be 150,000,000 tons, sufficient to keep a high capacity mine going for some 30 years. The exploration drilling program has been completed and a 1,200-meter (3,940-feet) shaft has been sunk from which prospecting development has been undertaken. The initial plan included the establishment of a complete processing facility. This has been shelved due to the current prevailing low copper price.

The Gyöngyösoroszi lead-zinc mine, Matra Mountains, supplied 106,000 tons of ore, from which 937 tons of lead and 2,680 tons of zinc concentrate were produced. The reserves are nearing depletion. Prospecting is underway but no significant results have been achieved to date.

Hungarian metals and minerals production in metric tons

Commodity	1979	1980	1981
Hard coal	3,002,000	3,065,000	3,065,763
Brown coal	14,182,000	14,156,000	14,463,295
Lignite	8,475,000	8,479,000	8,413,123
Iron ore	532,476	426,480	422,475
Manganese ore,			
oxides	126,230	134,000	120,593
carbonates	4,641	472	1,372
Lead-zinc ores	146,455	145,297	106,863
Lead concentrate	1,875	2,081	937
Zinc concentrate	5,725	5,443	2,680
Copper concentrate	1,527	N.A.	—
Bauxite	2,976,000	2,950,000	2,914,021
Bentonite, raw	72,488	77,685	80,531
Bentonite, processed	N.A.	N.A.	52,515
Kaolin, raw	63,457	51,839	52,518
Kaolin, processed	N.A.	N.A.	7,024
Perlite, raw	97,895	99,270	95,190
Glass sand, raw	663,774	713,136	777,480
Foundry sand	N.A.	N.A.	691,579
Silica	758,732	N.A.	N.A.
Alumina	817,771	811,216	779,142
Crude aluminum	71,879	73,497	N.A.
Aluminum semi-products	N.A.	143,000	143,000
Pig iron	2,369,000	2,214,000	2,193,000
Crude steel	3,240,000	3,763,000	3,600,000
Cement	4,900,000	4,660,000	4,600,000

N.A. Not Available. 1.0 metric ton = 1.1 short tons. 1.0 short ton = 0.907 metric ton.

The Pálháza mine, Tokaj Mountains, produced 95,000 tons of raw perlite and the Erdóbénye mine, 25,000 tons of diatomaceous earth. In the Kisórs field, Transdanubia, 692,000 tons of foundry sand were produced, while Fehérvárcsurgó mine supplied 777,000 tons of glass sand. The country's seven cement works produced 4,600,000 tons of cement.

The coal mines produced a total of 25,900,000 tons, of which 3,000,000 tons were sub-bituminous coals, 14,500,000 tons were brown coal, and 8,400,000 tons were lignite. Over the last 12 years no new mine has been opened. Two new mines, Márkushegy and Nagyegyháza, near Tatabánya are being developed and, in fact, longwall production has already started. Their maximum capacity of 2,000,000 to 2,400,000 tons per year will be reached in a few years. In the Dorog coalfield of Transdanubia another new mine, Lencsehegy 2 is to be developed.

IRELAND

Last year was relatively difficult for the mining industry. The continued weakness in base metal prices combined with high inflation in Ireland put serious financial pressure on the metal mines sector. An examination of the resources situation at existing mines (other than the Tara Mines Ltd. operation at Navan) allied with the lack of discovery of new ore bodies, in spite of a number of active exploration programs, makes it likely that within a few years there will be only one base metal mine in production.

During the first half of the year Tara Mines Ltd. announced a further rescheduling of their senior debt repayments, with resulting postponement of the date of final maturity of the loan. Production from their underground lead-zinc mine at Navan during 1981 was seriously affected by a labor strike that halted mining in early July. This situation was not resolved until the end of the year. The Bula Ltd. appeal against the planning refusal for an open cast operation on the northern portion of the Navan lead-zinc ore body was refused in April 1981. The company has since submitted a plan for an entirely underground operation, which is still under consideration by the planning authorities.

While the Mogul of Ireland mine at Silvermines is now close to depletion of its reserves, a continuation of higher grades and somewhat improved zinc prices enabled the company to continue operations throughout 1981, although the future remains uncertain.

The Avoca copper mine in southeast Ireland continued to receive substantial state aid during 1981, without which it could not have sustained operations. Mine production showed a marginal improvement on the previous year, with milled output of 755,000 metric tons grading 0.58 percent copper. Chalcopyrite concentrates contained 3,389 tons of copper. By-product pyrite concentrates amounted to some 22,600 tons, all of which was sold to a local fertilizer manufacturer.

Mineral exploration in Ireland, with some 40 percent of the land area held under prospecting licenses, continues to be directed mainly towards the location of carbonate-hosted base metal and barite deposits in the Lower Carboniferous area. Although no significant previously undiscovered deposits have been located recently, a number of the country's marginal deposits and some of the better prospects are receiving renewed attention. A relatively high level of exploration activity was maintained in the metasedimentary and metavolcanic Dalradian rocks in counties Donegal and Galway, where the interest is principally in stratiform base metal and barite deposits. There is also continuing interest in the Lower Palaeozoic rocks of the Longford-Down massif and in southeast Leinster, where a variety of metals are being sought; these include lithium, tungsten, and gold, as well as copper, lead, and zinc. As in most other countries, however, the level of expenditure on uranium exploration has decreased sharply due to the depressed state of the market and the decreasing acceptability of uranium mining. Furthermore, the area of licensed ground is much reduced.

On the other hand, interest in industrial minerals has increased significantly, and a number of exploration companies who have traditionally only been involved in base metal exploration have recently diverted part of their exploration effort towards industrial minerals.

There has been a considerable revival of interest in the Irish coalfields. A major study of the potential for economic operations was carried out during the year and is expected to be published during 1982. A number of relatively small-scale mining operations resulted in a continuing modest output of anthracite and semi-bituminous coal. The possibility of an economic coal deposit off the coast near Dublin is currently being assessed.

Barite continued to represent the major part of non-metal production. Northgate Exploration Ltd. completed the milling of its stockpile of oxide ore at the Tynagh Mine. This ore, which was being processed principally for its silver content, was also rich in barite and provided a welcome source for Milchem Ltd.'s secondary recovery operation, which produced 33,009 tons of barite in 1981 from the Tynagh tailings. Milchem Ltd.'s other barite operation, the Lady's Well mine at Duneen, county Cork, produced 22,400 tons. Magcobar Ltd. continued to maintain Ireland's position as a world barite producer, despite static barite prices, with production of 218,530 tons. Tara Prospecting Ltd., acting on Geological Survey information, outlined a deposit of talc-magnesite on Inishboffin Island off the Galway coast; the deposit is currently under assessment. The same company has also identified another talc deposit near Westport, county Mayo.

During 1981 Quigley Magnesite was joined by Premier Periclase Ltd., as producers of magnesia derived from seawater. However, while the Quigley operation utilized dolomite (219,420 tons in 1981), the Premier Periclase process used limestone to produce high quality magnesia products. These products came on the market during the year.

Increased production at Cement Roadstone's dry process plant at Platin enabled the company to meet its total demands without the need for imports, though this was undoubtedly assisted by the depressed state of the building industry, which kept sales close to 1980 levels. The low level of building activity also affected the sales of gypsum products, but Gypsum Industries Ltd. was able to maintain normal production from its two mines near Kingscourt in county Cavan. A considerable amount of ground limestone (1,500,000 tons) for agricultural purposes was also quarried during the year by various operators.

ITALY

In 1981 the Italian mining sector witnessed a decrease in production of 4 percent and in employment of 10 percent, compared with 1980. Metalliferous production fell by 23 percent while the nonmetalliferous output shrank by only 3 percent.

This situation has been brought about by the progressive depletion of existing deposits and a lack of adequate incentives to explore for new deposits; declining grade of the ores mined; rising costs that outpace other countries; the growing financial difficulties of mining companies which deters them from taking the risks involved in investing in exploration; difficulties in finding the necessary manpower for underground mining and experts in new technology.

In February 1981 the council of ministers approved a bill on a mining policy for the country that is at present being debated in Parliament. Under this bill CIPI (Interministerial Committee for Industrial Planning) is to set the guidelines of mining policies and promote basic research, carried out either directly by the state or through ENI, IRI or the mining authorities of the regions, on the basis of reliable technical criteria. CIPI must also provide incentives for exploration, by giving grants, to all public and private companies involved, of up to 60 percent of the amount to be spent, to be repaid if the investigation results in a positive outcome. It is also expected to provide aid to projects that have reached the mining stage by contributing the interest to be paid, and to keep certain mining operations running for strategic reasons, with money from the government. It is to keep in active production those mines that are operating at a loss, if there are sound reasons to do so, and provide support to activities of applied research for the development of new technologies and for the improvement of existing ones. Finally, it is to make available special grants to ENI and IRI for mining investigations abroad and to ensure the covering of risks incurred by Italian companies making investments abroad.

It must, however, be pointed out that it is going to take a long time for these measures, which would certainly give new impulse to the Italian mining industry, to be approved .

A close look at the production levels of 1981 shows a picture which is certainly not very promising. In the metalliferous mining sector the decrease in the output of lead and zinc is attributable to the closing of some important mines in the Alpine range (Salafossa and Gorno) and in Sardinia (Iglesias). At present production is ensured mainly by the Silus mine (lead) and the Masua mine (lead and zinc), however, in early 1983 the Fenice Capanne (Tuscany) mines should start production. Here, development work consisting of the construction of a spiral decline and lowering of the water table, continues. The initial results of investigations carried out at Monteneve in Campiglia Marittima, southwestern Sardinia, appear to be promising for the production of lead, copper and zinc.

Iron ore production has dropped because of the closure of some mines on the island of Elba. At present, the results of a technical-economic survey carried out by a special committee of the ministry for state participation, are being assessed. The aim of the study is to assess whether Italsider (of the IRI Group) should continue its mining activities.

Italian production of metals and minerals in metric tons

Commodity	1979	1980	1981
Antimony ore	1,835	1,400	1,323
Iron ore	218,762	184,733	123,407
Lead concentrate (64 percent Pb)	35,220	26,941	21,030
Zinc concentrate (54 percent Zn)	103,501	79,190	43,785
Zinc concentrate (8 percent Zn)	4,086	69,188	65,685
Pyrite	804,469	858,992	681,000
Asbestos	143,931	157,794	137,086
Barite	214,630	203,038	177,005
Fluorspar	182,791	151,965	164,235
Feldspar	294,648	344,301	428,485
Talc	157,382	165,905	163,708
Salt	4,490,118	3,997,096	3,610,618
Potash salts	1,526,605	1,301,649	1,417,800
Sulphur ore	108,130	100,852	96,202
Bentonite	282,446	332,888	277,350
Marble	1,794,240	4,000,000	5,500,000
Lignite (20 percent H_2O)	2,122,926	1,932,571	1,957,960
Aluminum, metal	270,185	271,199	269,495
Antimony	792	676	792
Lead, metal	26,840	47,251	40,408
Zinc, metal	202,272	206,430	180,903
Cadmium	526	568	482
Silver, metal	33	36	55
Mercury	—	3	252

1.0 short ton = 0.907 metric ton. 1.0 metric ton = 1.10 short tons.

Production of mercury at Monte Amiata has been resumed. Following a resolution issued by CIPE (Interministerial Committee for Economic Promotion) the mines can produce about 20,000 tons of ore per year in order to meet domestic needs.

Within the framework of an agreement between Rimim (ENI) and the ministry of trade and industry, a preliminary investigation has recently been completed to assess further deposits of ore suitable for mining. The results of the investigation were positive and a more detailed research program is being worked out. The agreement is expected to be renewed next year and the investigations will be extended to the area surrounding Lake Como.

LUXEMBOURG

Mining activity in Luxembourg ceased in November 1981. Up to that date, iron ore production for the year was 429,080 tons, 24 percent or 131,085 tons less than in 1980. The average number of employees in the mining industry decreased from 226 to 170 and was in fact 165 at the time of the shut-down.

Iron ore imports to the country decreased to 6,275,192 tons compared with 7,872,580 tons in 1980. The quantity of ore from France fell again to 4,522,073, tons compared with 5,749,515 tons the previous year. Imports from other countries, notably Sweden and Brazil, also fell, to 1,753,119 tons compared with 2,123,065 the previous year. No iron ore was exported.

Steel production was somewhat lower at 3,790,000 tons compared to 4,618,000 tons in 1980. Pig iron production was reduced by a total of 678,423 tons, falling to 2,889,320 tons.

Luxembourg production of iron ore and steel, and imports of iron ore in metric tons

Commodity	1979	1980	1981
Iron ore production	530,238	560,165	429,000
Iron ore imports	8,481,955	7,872,580	6,275,192
Steel production	4,949,698	4,618,650	3,790,000

1.0 short ton = 0.907 metric ton. 1.0 metric ton = 1.10 short tons.

NORWAY

The fluctuations of the base metal prices meant that the year 1981, as a whole, was a poor one for most of the Norwegian complex sulphide mines. The strong increase in pyrite prices, however, was the year's good news. Pyrite production in Norway decreased from about 800,000 metric tons in 1973 to less than 250,000 tons in 1979. Over the two last years, production has gone up, and several mines are planning to increase or to start production of pyrite. A few mines have stockpiled their pyrite concentrate pro-

The prolonged negotiations for a deal between Orkla Industries and Outokumpu Oy concerning Loekken Mine have been finalized and approval granted by the government. A new company, Loekken Gruber A/S & Company, has been formed with each party holding 50 percent of the shares. A long term contract for the sale of copper concentrate to the Outokumpu smelter in Finland was signed. Orkla Industries will be the operating company.

Last year was another difficult one for A/S Sydvaranger. In March the government put together an economic package to support the company. It was for $162,000,000 and included loan reduction, working capital, increased share capital and guaranties for new loans. The capital requirement of the company's new sponge iron plant in Emden, West Germany, was also part of the deal. Part of the arrangement was to split A/S Sydvaranger into three separate companies based on iron ore, sulphide ores, and prospecting. At the same time the company was urged to rationalize production.

During the year Sydvaranger finished the expansion of its processing plant. A new ball mill, 6.5 meters (21.3 feet) in diameter by 9.65 meters (31.7 feet) long, with an 8.1 megawatt ringmotor, was installed. At the same time a plant for reverse flotation of the iron concentrate came on stream. This plant was needed to meet the requirement for SiO_2 content in pellets. The new plant is reported to be very successful. The contractor was Aker Trondelag.

Norwegian mine and smelter production in metric tons

Commodity	1979[1]	1980[1]	1981[2]
Iron concentrate[3]	4,065,689	3,823,600	4,063,500
Ilmenite concentrate[4]	819,815	827,827	657,700
Pyrite concentrate[5]	240,553	421,367	412,600
Copper concentrate[6]	113,492	113,857	113,300
Zinc concentrate[7]	53,773	51,955	56,350
Lead concentrate[8]	5,211	4,467	5,590
Nickel concentrate[9]	14,830	12,090	12,000
Graphite concentrate	11,892	10,406	8,665
Coal	280,280	288,412	312,754
Feldspar	87,888	67,559	N.A.
Nepheline syenite	241,131	231,339	223,152
Limestone	5,254,309	4,146,386	N.A.
Dolomite	513,350	559,117	N.A.
Quartz	639,487	843,762	N.A.
Olivine	791,988	1,101,739	N.A.
Fillers	185,196	204,579	N.A.
Cement	2,251,000	2,206,000	1,781,771
Silicon carbide	63,657	58,901	53,660
Calcium carbide	94,278	89,579	78,900
Pig iron	650,235	611,660	570,000
Steel ingots	923,078	854,125	847,170
Ferrosilicon[10]	337,008	319,983	273,606
Other ferroalloys[11]	564,202	494,720	447,500
Aluminium	663,916	653,377	632,783
Magnesium	44,117	44,352	47,600
Copper metal	27,339	33,690	31,950
Nickel metal	30,686	37,123	37,100
Cobalt	953	1,275	1,445
Zinc metal	77,763	79,416	80,280
Cadmium	115	130	117

1. Official figures. 2. Preliminary figures. 3. 64.3 percent Fe. 4. 44.5 percent TiO_2 . 5. 50 percent S. 6. 25.3 percent Cu. 7. 52.7 percent Zn. 8. 57.5 percent Pb. 9. 4.0 percent Ni. 10. 75 percent Si. 11. Ferrochrome, ferromanganese, ferrosiliconmanganese, ferrosilicon-chrome, others. N.A. not available. 1.0 short ton = 0.907 metric ton. 1.0 metric ton = 1.10 short tons.

The wet high intensity magnetic separation plant at Rana Gruber started operation late last year. The Rana ore is predominantly hematite with some magnetite. It was previously processed by spirals, low intensity magnetic separation and reverse flotation of the hematite concentrate. In the new plant the ore is treated wholly by magnetic separation; magnetite is first extracted by low intensity magnetic separation and then hematite using high intensity equipment through three consecutive stages. The new plant is reported to give improved grades and recoveries.

Elkem's take over of Union Carbide's ferroalloy plants in the United States and part of its research division in Niagara Falls was accomplished in 1981. Elkem's ferroalloy plants are now organized into two divisons, Ferroalloy Norway and Ferroalloy United States.

POLAND

Polish copper started moving into Western Europe again in early 1982 following a long interruption of supplies following the declaration of martial law. Poland has been the largest copper producer in Europe with an output of around 400,000 metric tons of refined metal per year—prior to the internal problems. Exports of copper in 1981 were expected to amount to 159,000 tons, from a total production of 340,000 tons, and those of silver to be 500 tons (16,000,000 ounces).

According to the official news agency, the Lubin basin copper mines will produce 26,500,000 tons in 1982, yielding 330,000 tons of metal. Half of this output will be exported.

Aluminum production will drop from 100,000 tons in 1980 to 47,000 tons in 1982, according to official Warsaw reports. Worker protests forced the closure of the Skawina aluminum smelter near Krakow on environmental grounds. Currently, the only smelter is at Konin in central Poland. To meet domestic demand, estimated at 160,000 tons per year, Poland will have to import from Hungary and the Soviet Union.

Polish sulphur mining activities continued without serious disruption and 3,800,000 tons were exported, only 10 percent below the 1977 peak. Production from the three mines, Jeziorko, Gryzbow, and Machow, was reported to be 4,720,000 tons and the target for 1982 is 4,750,000 tons.

It is planned that up to six new rock salt mines will be developed by 1985 and national production is to be increased to more than 6,000,000 tons. Proven salt reserves amount to an estimated 52,000,000,000 tons. There are currently seven operating mines with an annual output of around 4,000,000 tons.

It is reported that there was a 15-percent increase in coal production between January and April 1982 and the concurrent improvement in mining of copper and other raw materials has brightened the economic picture. Coal production was 163,000,000 tons last year and the target for 1982 is 185,000,000 tons.

PORTUGAL

The alterations to the Portuguese mining law, expected for many years, seem now to be on the verge of becoming reality. The board of ministers has approved the project, which will now have to be discussed by parliament.

Participation of foreign capital continues to be welcome and provisions have been introduced permitting the board of ministers to approve a majority of foreign participation in cases of great interest to the country.

A large proportion of mining projects are developed by the public sector or predominantly under its management. Examples are the Aljustrel pyrite project, the Moncorvo iron project, uranium mining, etc. During 1981 these projects have been affected by budget cuts or by decisions to re-assess the industrial projects planned to process the raw materials.

Progress has been modest at all of them. Moncorvo completed the basic engineering work and the construction of a pilot plant. Orders for equipment are pending. While some development of infrastructure has been achieved, one of the major decisions—transport of ore to the steelworks, in principle to be achieved by rail—did not yet receive final approval.

The Aljustrel pyrite expansion program is subject to delays arising from the decision to re-assess the feasability of the Sines metallurgical project, which will consume most of the production.

Portuguese metal and mineral production in metric tons

Commodity	1979	1980	1981[1]
Anthracite	179,118	177,453	183,797
Ferro-manganese	37,440	41,850	37,000
Copper concentrate	2,103	3,009	2,434
Tin concentrate	346	391	508
Gold and silver (sulphide) concentrates	1,751	1,505	1,576
Columbium and Tantalite	3	4	9
Titanium concentrate	390	234	334
Tungsten concentrate	2,219	2,654	2,342
Barite	704	1,200	1,450
Diatomite	3,200	2,310	3,090
Feldspar	38,315	40,802	42,435
Cupriferous pyrite	349,172	387,170	286,620
Quartz	130,260	124,538	116,206
Salt	408,155	401,276	408,145
Talc	2,748	2,598	6,363
Uranium	134	95	120
Washed kaoline	47,088	49,724	52,846
Non-washed kaoline	20,084	12,455	16,512

1. Provisional figures. 1.0 short tons = 0.907. 1.0 metric ton = 1.10 short tons.

The national uranium company, expects to have the Nisa area feasability study completed this year. Association of the state company with national or foreign private or other companies, is welcomed.

Work on the Neves-Corvo copper mine is proceeding well. A total of about 50,000 meters of diamond drilling has indicated reserves of 60,000,000 tons of various types of cuprifereous or complex minerals.There are two ore bodies, at depths of 300 and 700 meters inclined at up to 25°. A vertical, 5-meter diameter, shaft for extraction designed to reach 700 meters in depth and a 17-square-meter cross-section ramp at a gradient of 18 percent, projected to be 5,000 meters long, are advancing.

This project, for the production of 1,000,000 tons of copper concentrate per year commencing in 1986 and 1,000,000 tons per year of complex minerals commencing in 1990 will represent a total investment above $200,000,000. The initial production will be 200,000 tons of 25-percent copper concentrate per annum. Equipment supply companies will be invited to present their pre-qualification in 1983.

Prospection work continues in various areas. Utah will shortly be drilling for pyrite in Alentejo. BRGM/SPE will be investigating the pyrite of Caveira area. Anglo/SPE is expected to begin prospecting for gold in the north of Portugal this year. Beralt is proceeding with the mechanization program (to be completed in 1982) of Panasqueira tungsten mine.

Due to the world energy situation the government decided to invest in a new state company the exclusive right to investigate national coal resources by prospecting and researching new origins of coal and by investigating the possibilities still existing in the old mines, such as S. Pedro da Cova (Oporto) and Rio Maior (Santarem). These mines have not produced for many years and the feasability of reopening them will be now assessed. The construction of power plants located at the mine site is to be studied. Pejao coal mine, now supplying a power plant in Oporto, will be investigated to discover the real position of reserves in that area.

SPAIN

The mining industry achieved substantial production increases in the first half of last year but in the last months of 1981 several companies had to cope with pricing problems and a severe drought in central and southern Spain. Potasas de Navarra had to stockpile part of its production and the Union Explosivos Rio Tinto potash mines in Catalunya had serious export difficulties because of Soviet exports to the Mediterranean markets. The Almadén mercury mines maintained production and profited from higher international prices, although these declined later under pressure from the United States. Most of the iron ore mining companies came close to their production targets but the state-owned Ensidesa steel company will discontinue its purchases of about 500,000 tons per year of low-grade iron ore from the Minero-Siderurgica de Ponferrada's (MSP) Coto Wagner mine in north-west Spain.

The combined impact of low prices and the long drought forced Andaluza de Pirita to an almost complete discontinuation of operations at its 1,000,000-ton per year Aznacollar pyrite mine for about six months. This will reduce zinc production by at least 50,000 tons. The state-owned Minas de Almagrera decided to reduce to about $50,000,000, its investment in a new sulphuric acid plant at Sotiel in southwest Spain and to halve the production target of the projected plant.

Alumespa's San Cipriano aluminum plant obtained a substantial rebate on electric power prices and aware of the difficulties faced by Spanish mining companies and in accordance with the Law for the Promotion of Mining, the government issued another round of invitations to obtain financial aid. Special priority will be given to investments made in the exploration and production of gold and silver ores, feldspar, glauberite, thenardite and mercury. Iron ore output is to increase by 600,000 tons of Fe-content. Of an annual production of 60,000 flasks of mercury, 45,000 will be for export. Production of zinc ores is to increase by an annual 230,000 tons and tin metal by 160 tons, plus 400 tons recycled tin. The output of lead metal should increase by 34,000 tons; feldspar by 80,000 tons; tungsten by 243 tons; and production of copper metal is to increase by 40,400 tons, plus 22,400 tons from copper scrap. The government will welcome foreign investment to help finance the expansion program.

In accordance with the national energy plan, Empresa Nacional de Uranio, S.A. (ENUSA) received more funds to accelerate the construction of the Juzbado plant for the preparation of fuel for pressurized boiling-water reactors. Spain has its uranium requirements covered at least until 1987 when—at the rate of about two plants coming on stream per year—a total of 12 to 14 nuclear power plants will be operating.

Joint ventures formed by foreign and Spanish companies have intensified uranium exploration and development work in several regions. Spain's total uranium reserves are now assessed at about 30,000 tons U_3O_8, including the largest ever sedimentary deposit discovered in Spain at Molina de Aragon.

A boom is expected in the industrial minerals sector. The Aislamic company is completing a new feldspar concentration plant at El Cabril, located in southern Spain, which will have an annual production capacity of 200,000 tons of feldspar, mica and quartz products.

The Rio Tinto Minera controlled Caolinas de Vimianzo obtained foreign credits for the development of kaolin deposits in northwest Spain and for the construction of a processing plant with a 100,000 tons per year output of washed kaolin. In central Spain Caobar-Cecsa is also expanding its production capacity.

The Foret company embarked on a large scale exploration program, hoping to discover carbonates, chlorates, sulphates and other raw materials for chemical production.

Also, in the Duero river valley and adjacent regions, Tolsa is prospecting for sepiolite and bleaching clays on several claims amounting to a total of 100,000 hectares (246,900 acres).

Coal miners gained more than metal miners from over $300,000,000 that the government had earmarked last year to help finance exploration, development and mining of minerals. As a result, the production of lignite increased by 25.8 percent and that of anthracite by 15.5 percent. For the first time in its history, the state-owned Hunosa reached its 4,000,000 tons production target.

As several lignite deposits were discovered in Andalusia and Galicia, Spain's total coal output may reach a peak of about 38,000,000 tons in 1985. Further increases do not seem feasible, but to ensure future coal supplies, and reduce Spain's dependency on oil imports as a consequence, Spanish companies are purchasing participations in overseas coal mining ventures.

Spanish production of ores and metals in metric tons[1]

Commodity	1979	1980	1981
Iron ore, expressed in metal content	3,983,800	4,372,325	4,115,154
Pyrite, copper bearing	2,366,000	2,513,757	2,411,164
Pyrite expressed in sulphur content	1,091,000	1,152,249	1,102,653
Potash, K_2O salt	687,000	660,420	860,754
Zinc concentrate	242,168	273,000	268,000
Zinc	142,745	193,120	175,166
Lead concentrate	101,680	124,000	121,000
Aluminum[2]	259,890	386,450	400,000
Copper[3]	35,982	45,068	45,467
Barite, $BaSO_4$	67,500	68,200	63,000
Fluorspar, acid grade	162,500	198,162	252,680
Fluorspar, metallurgical grade	85,500	54,000	48,000
Mercury	1,070	1,656	1,600
Pig iron	6,450,000	6,520,000	6,600,000
Steel	12,254,000	12,671,000	12,690,000
Coal	22,035,000	26,500,000	30,800,000
Cement	28,100,000	28,044,000	28,000,000
Tungsten[3]	407	563	419
Tin[3]	451	437	483
Magnesite, calcined	94,600	133,697	120,000
Sepiolite	234,712	252,304	250,000
Gold[3]	2,841	2,980	2,900
Silver[3]	98,597	102,000	98,000
Uranium, U_3O_8	336	360	370

1. From Spanish Ministry of Industry, company reports, and WORLD MINING research. 2. Extracted from local ores only, not including imported materials. 3. Kilograms. 1.0 metric ton = 1.1 short tons. 1.0 short ton = 0.907 metric ton.

SWEDEN

By **Sven-Gunnar Bergdahl**
Managing Director
Swedish Mining Association
Stockholm

Production from the Swedish iron ore mines decreased by 15 percent compared with 1979. Howver, production of sulphide ores increased by about 22 percent. The total amount of iron ore products and processed sulphide ores was 37,800,000 tons compared with 38,800,000 tons in 1980. At the beginning of the year, there were six producing mining companies.

Deliveries of iron ore amounted to 20,100,000 tons compared with 24,500,000 tons in 1980. Domestic deliveries were 2,300,000 tons. The Lapland mines accounted for 94 percent of exports and 59 percent of domestic deliveries. At the end of the year iron ore stocks amounted to 10,700,000 tons, a build-up of 3,100,000 tons over the year. Of the production from the central Swedish iron ore mines 52 percent was exported.

Production of sulphide ores was 14,600,000 tons compared with 12,000,000 tons in 1980.

Due to a lower level of deliveries, 18,200,000 tons compared with 21,100,000 tons in 1980, Luossavaara Kiirunavaara AB (LKAB) was forced to suspend production for eight weeks during the summer. In Kiruna, production was stopped for another week in the autumn and for seven weeks, production ran only 4 days per week.

During 1981, stocks increased by 2,200,000 tons to 8,800,000 tons. In December, production started at the new pelletizing plant in Kiruna, with an annual capacity of 3,500,000 tons. LKAB's total pelletizing capacity is now 9,500,000 tons per year, not counting the shaft furnace in Malmberget, which has been shut down.

Svenskt Stål AB shut down its pelletizing plant at Stråassa on April 30 and at the end of the year, production of coarse concentrate ceased.

A new plant to produce granulated concentrate will start up at Grängesbergs in late 1982. Existing equipment in the plant for cold-bound pellets will be modified and completed with screening plant and space for hardening. Full scale tests on granulated concentrate have been carried out at Oxelösund, with very positive results. International interest in the project is high.

At Dannemora, earlier intensive exploration work has revealed large ore reserves. Without any shaft sinking or installation of new crushing plant, existing reserves are sufficient for full production beyond year 2000. During 1981, 550,000 tons of ore were produced. Deliveries were only 340,000 tons. Since October 1981 only 75 percent of capacity has been utilized.

Boliden Mineral AB operated 15 mines and 8 processing plants in 1981. A total of 13,500,000 tons of ore were mined and

Swedish mineral production in metric tons

Commodity	1979	1980	1981[1]
Iron ore products	26,619,000	27,184,000	23,225,000
Pyrite concentrate	448,000	396,000	421,000
Copper concentrate	192,000	181,000	222,000
Lead concentrate	115,000	102,000	123,000
Zinc concentrate	303,000	306,000	334,000
Cement	2,346,000	2,438,000	2,320,000
Talc	5,000	3,000	4,000
Apatite	58,000	88,000	124,000
Scheelite	700	600	700

1. Preliminary figures. 1.0 metric ton = 1.1 short tons. 1.0 short ton = 0.907 metric ton.

Production of iron ore, concentrate, and pellets by Luossavaara-Kiirunavaara AB in metric tons

Mine	1978	1979	1980
Kiruna			
Ore	13,820,000	13,330,000	12,000,000
Pellets	470,000	1,240,000	300,000
Total	14,290,000	14,570,000	12,300,000
Malmberget			
Concentrate	2,600,000	3,540,000	4,100,000
Pellets	3,440,000	2,590,000	1,700,000
Total	6,040,000	6,130,000	5,800,000
Svappavaara			
Ore	520,000	600	100,000
Pellets	2,300,000	2,430,000	2,100,000
Total	2,820,000	3,030,000	2,200,000

1.0 short ton = 0.907 metric ton. 1.0 metric ton = 1.10 short tons.

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processed. During 1981, prospecting activities have been stepped up by about 20 percent. A new method of airborne prospecting has been patented, allowing the electric properties of the bedrock to be determined over a much wider spectrum than before. The possibilities of utilizing the new method for deep prospecting are now being evaluated.

Deep prospecting in the Skellefteåa area has shown interesting indications. Nickel prospecting in southern Norrbotten has given some promising results.

At Aitik, the increased capacity could not be fully utilized due to unexpectedly hard ore and technical problems in the processing plant. These problems now seem to be solved and a considerable increase of production is expected for 1982.

Very extensive exploration work in the Vassbo area gave negative results and a shut-down is now planned. In 1981, tests of a unique method to utilize ice for filling and stabilizing stopes started. A technical and economical evaluation will be carried out in 1982. Hornträskgruvan in the Kristineberg area started up in late 1981 with an annual capacity of 70,000 tons.

Underground prospecting at the Falu mine of Stora Kopparberg has revealed relatively rich mineralizations of copper, lead and zinc, adjacent to the present mining area. The change-over to solely underground mining is proceeding according to plan.

At Vieille Montagne efforts have been aimed at reducing waste rock dilution of the ore. The results have been very good. From 575,000 tons of hoisted ore, production of lead and zinc concentrate exceeded budget for 1981, based on 600,000 tons of ore. In consequence, flotation and dewatering capacities have been fully utilized.

Production of cement at Cementa AB's plants at Slite, Skövde and Degerhamn was according on target. The plants at Slite and Degerhamn are now using only coal as a fuel. Deliveries of cement in Sweden were reduced during 1981, but exports increased, giving a total production of 2,400,000 tons, the same as 1980, from 3,800,000 tons of raw material excavated. In addition, 2,100,000 tons of limestone products were made from 2,700,000 tons of raw material.

Exploration by Höganäs AB has revealed 20,000,000 tons of low-sulphur coal in seams of sufficient thickness for mechanized underground mining. The sulphur content is only 0.4 percent, and the ash content is 25 percent.

Ernström Mineral AB's production of white dolomite was 302,400 tons during 1981. In order to prevent subsidence on the surface, cable bolting of the hanging wall is planned. A system of sensors grouted into drill holes will register stress changes and movements.

UNITED KINGDOM

A number of new barite projects are being opened, due largely to the current demand for drilling mud. SPO Minerals reports that its new operations in Derbyshire alone should yield 3,400 tons annually. SPO has sought planning permission to mine barite from an old mine in Caldbeck Fells, whilst Braithwaite mine, near Keswick, is being refurbished for the production of lead and zinc, as well as barite. In Scotland, Dresser-Magcobar continue working at Aberfeldy, and have outlined reserves of 2,000,000 tons. Some interest is also being shown in Devonshire and Somerset.

The dramatic fall in the tin price had a serious effect on the mining industry in Cornwall. Geevor showed a loss for the year ending March 31, 1981. Commissioning the new treatment plant resulted in a 37-percent increase in overall throughput, and production of concentrate rose by 170 tons to 1,251, but during the year the price of tin fell. Owing to this situation, the re-opening of Allen's shaft at Botallack was postponed, but is likely to go ahead with an improved and stable tin price.

South Crofty commissioned a $10,500,000 expansion to raise production by 45 percent over the next five years. The work includes further shaft sinking and alterations in the treatment plant. During the year, Carnon Consolidated Tin Mines announced a new$5,200,000 development program for Wheal Jane. The work entails deepening Clemows shaft and relocating the crusher station. As a result, a further 750,000 tons of ore will be made available. A connection has been made with Mount Wellington so that the two properties can be worked as one mine. It is reported that the mine is producing 25 percent more tin annually than under its former management.

South West Consolidated Minerals has been granted planning permission for a $27,500,000 venture at Redmoor, near Callington. It is anticipated that production at the mine will build up to a maximum of 1,200 tons of cassiterite ore per day, and that it should ultimately be capable of providing between 15 and 20 percent of the country's tin requirement. Wheal Concord, a new mine, discovered some high grade tin ore near Redruth, and indeed, has gone into production only fifteen months after the venture was started, 3,000 tons of ore having been treated at the Wheal Jane mill.

Amax Exploration and its partners have applied for planning permission to develop a mine and treatment plant at Hemerdon near Plymouth, following the satisfactory outcome of pilot plant tests. It is envisaged that full production will be about 2,200 tons of tungsten in concentrate per year. To date the reserves stand at 42,300,000 tons, with an overall grade of 0.08 percent WO_3 and 0.029 percent tin. In the meantime, Billiton (U.K.) Ltd., has purchased an option to buy the 50 percent interest in Hemerdon held by Hemerdon Mining and Smelting Ltd., the remainder is held by Amax.

Cornish Tin and Engineering has applied for planning permission to work beach sand at Hayle, whilst Marine Mining have been refused planning permission to dredge the St. Ives bay when the company had spent $1,700,000 on a pilot project. Gopeng Consolidated has decided to cease exploration at Porkellis Moor near Helston, whilst Billiton have also decided not to go ahead with working Rostronguet Creek on the River Fal.

A molybdenum bearing vein has been discovered in Unst in the Shetland Isles,

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and is said to carry 0.23 percent molybdenum over a meter in width. Prospecting for gold and silver is to be undertaken in the vicinity of the Ogofau mine in Wales, which last operated in 1938.

English China Clays reported a consolidated profit increase of $2,050,000 compared with the previous year.

The coal industry has improved its production, and reported a trading profit of $1,050,000,000 for 1981. Exports have been appreciable, and a $3,700,000 coal export terminal is to be built at Workington, Cumbria, with a capacity of 2,000 tons per hour. Fifteen months since the public enquiry into the development of three new coal mines in Leicestershire, no decision has been reached by the Secretary of the Environment.

WEST GERMANY

The decline in economic activity that was first felt back in the second quarter of 1980, deepened in the course of 1981 to a marked recession in the second half of 1981. The consumption of non-ferrous metals in 1981 remained below the previous year's level. Cutbacks in production in non-ferrous metal smelters and foundries were unavoidable.

The success of the efforts of metal producers to make more use of domestic sources of primary materials is shown by the metal supplies balance-sheet for 1981. The proportion accounted for by foreign supplies fell from 79 percent in the previous year to 71 percent in the year under review.

Refined metal production increased slightly by 10,000 metric tons to 1,835,700 tons, while consumption of the principal non-ferrous metals, such as aluminum, copper, lead, zinc, nickel and tin decreased by 80,000 tons or 3 percent to 2,533,000 tons.

At a level of 139,700 tons of metal contained in lead and zinc, the production of the mining industry fell by 9 percent against the previous year. While the output of refined lead and zinc remained about the same as in the year 1980, the production of refined copper increased by 3.6 percent to 387,300 tons.

Production from West German copper smelters could be seriously endangered by a lack of raw materials in the foreseeable future. Protectionist measures by southeast Asian countries were blamed for the distortions in competition for raw materials.

The production of primary aluminum decreased only marginally by 0.3 percent to 728,900 tons; consumption fell by 4 percent against the previous year, to about 1,000,000 tons. The existing capacity was, for the majority of the year, fully utilized in 1981. The situation in the secondary aluminum sector was affected by the continued adverse position in the steel industry and only slow recovery in the course of the year in the motor industry.

The two major zinc producers announced production cutbacks in January 1982, reflecting the poor demand for the metal. Preussag AG is to cut its zinc output at its Harlingerode smelter by 30,000 tons this year from last year's level. Metallgesellschaft AG reduced production at its Berzelius smelter in Duisburg by 20 percent during the first quarter, or roughly about 4,000 tons.

The pilot plant for the QSL process, which was built by Lurgi and is operated jointly by Metallgesellschaft AG and Preussag AG, has been running in Dusiburg since March 1981. This process for the continuous production of lead has ful-

West German smelter production in metric tons

Commodity	1979	1980	1981
Aluminum	741,900	730,700	728,900
Lead (refined)	373,300	350,300	348,300
Copper (refined)	382,500	373,800	387,300
Zinc (excluding dust)	355,500	365,200	366,600
Tin (unalloyed)	4,100	2,300	1,800
Tin alloys	3,700	3,200	2,800
Solder	17,100	17,100	16,800
Cadmium	1,300	1,200	1,200
Silver	507	758	N.A.
Gold	9.1	9.3	N.A.
Pig iron	35,167,000	33,873,000	31,876,000
Steel ingots and castings	46,040,000	43,838,000	41,610,000

1.0 short ton = 0.907 metric ton. 1.0 metric ton = 1.10 short tons.

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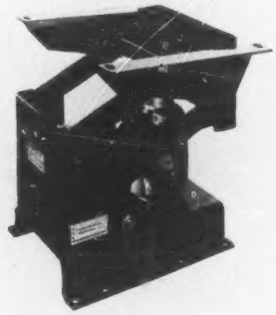

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filled expectations regarding low pollution levels, energy consumption and costs.

Output from the coal mines went up further in 1981 to 88,500,000 tons, while lignite production increased slightly to 130,600,000 tons. There are proven reserves of about 56,000,000,000 tons of lignite, 55,000,000,000 tons of which are found in the Cologne, Aachen, Dusseldorf triangle. Based on current energy prices, some 35,000,000,000 tons of this lignite can be mined economically.

West German mine production of ores and metals in metric tons

Commodity	1979	1980	1981
Lead ore[1]	33,000	31,300	29,000
Zinc ore[1]	117,100	120,800	110,700
Copper ore[1]	2,200	2,600	2,800
Silver in ore[1]	36.7	37.7	39.3
Pyrite[2]	244,005	264,531	199,905
Iron ore, crude weight	1,659,000	1,945,000	1,572,000
Iron ore, iron content	530,000	595,000	476,000
Potash salts, crude weight	27,674,263	29,317,000	28,192,000
Potash salts, K_2O content	3,171,000	3,307,000	3,141,000
Salt, (rock and evaporated)[3]	15,090,000	12,500,000	13,500,000
Graphite[4]	10,282	11,255	10,445
Fluorspar	63,000	78,000	68,000
Barite	175,000	187,000	177,300
Coal			
Anthracite and bituminous	86,319,999	87,000,000	88,500,000
Brown coal	130,608,000	129,862,000	130,600,000
Cement	35,481,000	33,135,000	30,207,860

1. Recoverable metal content. 2. Sulphur content. 3. Including NaCl. 4. Including imported graphite, unwrought. 5. Preliminary 1.0 short ton = 0.907 metric ton. 1.0 metric ton = 1.10 short tons.

YUGOSLAVIA

The majority of the work in expanding the Kat-Kombinat Aluminijama alumina plant and aluminum smelter in Titograd (Socialist Republic of Monte Negro) was completed. The integrated plant will now produce some 100,000 to 110,000 tons of electrolytic aluminum (previously only 50,000 tons), about 50,000 tons of anode-material (up to now only 25,000 tons) and 280,000 tons alumina (compared with 200,000 tons previously). A second, and final stage of modernization is still to be accomplished.

At the TGA Kidri$hcevo alumina and aluminum complex, the first in the Republic of Slovenia, production has risen from 40,000 tons alumina and 15,000 tons aluminum to 80,000 tons alumina and 25,000 tons of aluminum. However, the old electrolysis equipment is to be taken out of production in the years 1983/84. A new aluminum smelter is already being prepared and its capacity should reach 30,000 tons and more. Regular production is planned to begin during 1984 or 1985. At the same time a modernization and expansion of the alumina plant is being planned. Its capacity should be, by 1984/85, about 160,000 tons. Also a new foundry and a new rolling mill with a capacity of 20,000 tons has been planned at Kidri$hcevo.

Exploration on the island of Istra has located, near Laborike, the community Pulj, reserves of high-quality bauxite. Reserves are estimated to be 2,500,000 tons. Open pit mining will be possible for 15 years, beginning during 1982.

During previous years the Rudnik lead-zinc mine has produced about 170,000 tons of ore per year. Recently completed geological research has proved further reserves of high quality ore. The mine will increase its production to 230,000 tons yearly and the mine's life will be extended from the present 16 years to 30 years. The mine belongs to Rudarsko-Metalurski Kombinate Trepca (RMHK Trepca).

RMHK Trepca has carried out an investigation recently and concluded that the investment in geological research is too low, because the intensity of exploration in all mines increases yearly by 19 percent, but proven reserves increase by only 2.15 percent. That meant for about nine times greater exploitation than the discovering of new reserves. Further, of the ore mined, only 50 percent to a maximum 70 percent of the economic constituents, lead and zinc, are extracted. To discover 1 ton of ore it is necessary to invest up to $4.00 in the Trepca mines.

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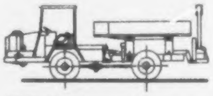
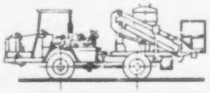
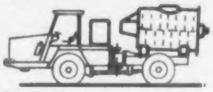


Platform truck with crane



Explosives charging truck with lifting platform



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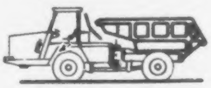

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At present, the mines Kisnica and Novo Brdol have a life of seven years each, the Stari Trg mine has a life of 15 years, the life of the Lece, Suolja, Stena, and Ajvalija mines is four years each, and the Bokovac mine has a life of only two years. Thus, exploration is to be intensified over the next few years. Some $4,500,000 is to be invested in exploration each year.

At the beginning of the 1981 year, mining of copper ore began for the first time in Macedonia. The Bucim mine, located near Radovis, will produce, annually, about 100,000 tons of concentrate, which will be refined by RTB-BOR to about 22,000 tons electrolytic copper yearly. The concentrate from here also contains some silver and gold.

After one year of operations it is already clear that the Bucim mine will not be able to reach the planned yearly production. During 1980 the mine production resulted in some 60,000 tons concentrate, enough for the production of 16,000 tons copper. The grade being mined is under 0.7 percent copper, not the 1.5 percent that was expected.

The copper mine of Veliki Krivelj near Bor in Serbia will, because of shortage of finance, not begin production until 1983. According to the plan, regular production should have started in 1981. The yearly mine production will be 8,000,000 tons of ore, from which about 30,000 tons of electrolytic copper will be produced by RTB—BOR. The ore also contains gold, silver, selenium, platinum, molybdenum, magnetite and pyrite.

Within the mining-industrial complex of Feni near Kavadarci in Macedonia a new, 36-kilometer long conveyor system has been set up. It will be used to transport ore from the Rzanovo nickel mine to the smelter in Feni. The yearly output will amount to 2,500,000 tons of ferronickel ore. Present geological research has reportedly proven major reserves of high-quality ore in this area, which will allow a mining life of at least 30 years.

It is estimated that current proven reserves are only one-third of the possible reserves. Further exploration is continuing. It is also thought that further reserves of ore to be proven will be of a higher grade than those of Rzanovo. The Feni smelter is expected to be producing some 22,000 tons of ferronickel yearly, and about 500,000 tons of high-quality iron concentrate, according to current plans.

The testing of equipment in the Feni smelter was completed by the end of 1981 with the testing of one of the two electro-furnaces, which has an installed power of 76 megawatts. According to the plan the second electro-furnace should have started production, but owing to some technical problems it will now start as soon as possible in 1982. It is already foreseen that the first ferronickel exports will be to Poland.

The first phase of production, by the end of 1985, should see the smelter producing about 88,000 tons ferronickel containing 25 to 49 percent nickel. Production of nickel should reach 22,000 tons and iron concentrate about 530,000, containing 55 percent iron.

The magnesium plant in Baljevac, which is located near the river Ibar in Serbia began regular production at the end of 1981. During 1982 it is expected that 5,000 to 5,500 tons of magnesium metal will be produced. The first quantities will be exported to Japan. Japan plans to buy more than 4,000 tons of magnesium metal during the year.

Experiments at the Zorka plant near Sabac in Serbia to produce uranium concentrate from phosphoric acid have been intensified. The first results show, that the production costs will be about $35 per kilogram of concentrate.

As a result of intense exploration in Sipovo, Bosnia and Hercegovina, mining of high quality bentonite will be started by Rudnici Boksita Jajce. The reserves are estimated to be about 1,000,000 tons. Initial mining during 1981 produced about 3,500 tons of bentonite for the naphtha industry. As the mine becomes fully operational, it will produce about 30,000 tons annually.

Coal production of all types, hard coal, brown coal, and lignite, is to increase further.

Yugoslavian production of metals and minerals in metric tons

Commodity	1979	1980	1981
Refined lead	111,040	101,751	86,401
Zinc	98,905	84,537	96,370
Electrolytic copper	137,500	131,288	132,603
Antimony regulus	2,401	2,237	2,198
Mercury	—	2	6
Aluminum	189,522	184,760	198,767
Bismuth[1]	23,000	82,800	102,400
Selenium[1]	50,600	50,400	61,000
Silver[1]	162,000	149,000	138,100
Gold[1]	N.A.	N.A.	17,420
Pig iron	2,360,000	2,500,000	2,817,200
Steel	3,537,000	3,634,000	3,976,500
Ferro-alloys	250,000	243,000	264,300
Coal (total)	42,114,000	47,002,000	52,245,000
Hard coal	434,000	398,000	384,000
Brown coal	9,351,000	9,665,000	10,581,000
Lignite	32,349,000	36,949,000	41,279,000
Coke	2,486,000	2,628,000	2,693,000
Asbestos	10,041	12,106	13,591
Cement	9,021,000	9,315,600	9,779,000
Magnesite	293,000	262,000	300,000
Magnesite calcined	156,000	—	—
Salt	350,000	377,000	418,500
Fireclay	170,800	202,000	182,000

1. Kilograms. 1.0 metric ton = 1.1 short tons. 1.0 short ton = 0.907 metric ton. N.A. Not available.

Yugoslavian production of ores in metric tons

Commodity	1979	1980	1981
Iron ore	4,617,000	4,530,000	N.A.
Copper ore	16,446,000	19,559,000	18,337,000
Lead-zinc ore	4,155,000	4,284,000	4,365,000
Bauxite	3,012,000	3,138,000	3,249,000
Pyrite concentrate	—	522,000	618,000
Manganese ore	32,320	36,400	33,400
Chrome ore	2,820	3,070	—
Antimony ore	91,000	70,000	66,000

1.0 metric ton = 1.1 short tons. 1.0 short ton = 0.907 metric tons. N.A. Not Available.

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ARGENTINA

The Argentinian government continued to show interest in developing its major mineral deposits and in attracting foreign investment in 1981. An international symposium for foreign companies and banks interested in investing in Argentinian mining projects was planned for early 1982. The meeting would include discussion of the Ley de Promoción Minera, which is a two-year-old mining law that encourages foreign investment.

The main projects that the government has targeted for development are the Bajo La Alumbrera porphyry copper-molybdenum deposit, the Farallón Negro gold-silver-manganese deposit, and the Nevados del Famatina porphyry copper deposit.

The government helped finance several private exploration ventures. Companies receiving funding included: Cerro Castillo S. A., for an exploration program in Chubut; Compañía Minera el Colorado S. A., for prospecting at the Sentazon mine in San Juan; Compañía de Minas S. A., for continuing scheelite exploration at the El Duraznito mine in San Luis; Compañía Minera Sierra de Maz S. A., for fluorite prospecting at the Francisco mine in Cordoba; and Tantal Argentina SRL, for exploration at the King Tut mine in La Rioja.

Argentina's major zinc and lead miner, Compañía Minera Aguilar S. A., produced 33,362 tons of lead, 37,258 tons of zinc and 1,650,000 ounces of silver contained in concentrate at its Aguilar mine in fiscal year 1981. Reserves at year-end were 6,600,000 tons of ore assaying 6.2 percent lead, 7.6 percent zinc, and 3.7 ounces of silver per ton. Present reserves are sufficient for 11 years at current rates of mining.

Aguilar is a subsidiary of St. Joe Minerals Corporation, which merged with Fluor Corporation in 1981. Both are United States firms.

Argentine production of metals in metric tons

Commodity	1979	1980[1]	1981
Iron ore	950,000	1,000,000	1,000,000[1]
Lead	31,840	31,560	31,930
Zinc	37,100	33,470	34,920
Manganese	20,000	20,000	18,000[1]
U_3O_8[2]	157,800	220,400	398,000
Borax	128,000	128,000	125,000[1]
Sulphur	20,000	20,000	18,000[1]
Tin	450	600	600
Silver[3]	2,208,800	2,305,000	2,100,000
Gold[3]	10,100	11,000	10,900

1. Estimated 2. Pounds 3. Ounces

BOLIVIA

By **Oscar M. Dávila**
Consultaria Metalúrgica Minera

The year 1981 was a bad one for the Bolivian mining industry. Tin prices went down, mining equipment and material costs went up, and although production increased, income was lower than in 1980. As mining represents approximately 70 percent of Bolivia's income, the situation was devastating to the economy. According to the minister of mines, Colonel Carlos Morales, one of the most negative influences was overpriced metallurgical projects that were supposed to improve the Bolivian economy, but actually represented very large investments without satisfactory results.

The sulphide tin volatilization plant in La Palca, Potosí was completed in the second half of 1981 to have a daily capacity of 400 metric tons per day of low grade tin concentrate. An explosion at the start-up temporarily halted operations. The plant was again shut down on December 15, 1981 because of arsenic and sulphide oxide pollution. Engineers from the Soviet government and from Machinoexport, the Soviet company that designed and built the plant, were sent to the plant to get it back into operation. The plant's initial cost was set at $9,417,720, but has now been revised to over $70,000,000.

The expansion of Vinto tin smelter near Oruro was delayed until 1982 because of an explosion in the main electric furnace. Production is scheduled to be raised to 20,000 tons per year of metallic tin. The plant was built by Machinoexport, of West Germany, Klöckner Humbolt-Deutz, and Bergsoe, of Denmark.

Construction of the Karachipampa lead and silver smelter proceeded on schedule in 1981. The main problem encountered was the scarcity of domestically produced concentrate feed for the plant, which will have a 25,000-ton-per-year capacity. The $154,000,000 project is being jointly developed by Klöckner and Sidech, a Belgian company.

The government approved a new law for foreign and national investments that is viewed as favorable for the mining industry. Unfortunately, it is unlikely that much investment will come to Bolivia soon because of social, political, and economic conditions.

Bolivian metal and mineral exports in metric tons

Commodity	1979	1980	1981
Tin	26,617	22,530	29,780
Lead	15,673	15,936	16,757
Zinc	53,923	46,236	47,029
Antimony	16,635	12,622	15,301
Copper	1,740	1,675	2,637
Tungsten	2,647	3,435	3,449
Bismuth	46	547	11
Silver[1]	5,837,000	5,678,218	6,601,568
Gold[1]	N.A.	45,000	44,000

Source: Ministerio de Minas y Metalúrgia. 1. Troy ounces. N.A. Not available. 1.0 metric ton = 1.10 short tons. 1.0 short ton = 0.907 metric ton.

Corporación Minera de Bolivia's production of metals and minerals in metric tons

Commodity	1979	1980	1981
Tin	19,009	18,620	20,828
Silver[1]	4,772,863	5,123,140	5,492,915
Lead	9,551	10,152	9,598
Bismuth	10	10	9
Copper	1,765	1,797	2,622
Wolframite	1,356	1,576	1,424
Zinc	30,121	28,953	27,218
Cadmium	128	134	122
Gold[1]	N.A.	N.A.	N.A.

Source: Ministerio de Minas y Metalúrgia. 1. Troy ounces. N.A. Not available. 1.0 metric ton = 1.10 short tons. 1.0 short ton = 0.907 metric ton.

Bolivian production of metals and minerals in metric tons by size of mines

Metal	Comibol	Medium mines	Small mines	Total
Tin	20,828	6,314	2,638	29,780.00
Copper	2,622	—	15	2,637.00
Lead	9,598	4,359	2,799	16,756.00
Zinc	27,218	17,731	2,079	47,028.00
Wolframite	1,424	1,765	290	3,479.00
Silver[1]	5,492,915	786,535	322,118	6,601,568
Bismuth	9	—	2	11.00
Antimony	—	12,160	3,141	15,301.00
Cadmium	122	43	—	165
Gold[1]	N.A.	16,074[2]	50,297	66,371.00

Source: Ministerio de Minas y Metalúrgia. 1. Troy ounces. 2. Production from South American Placers Inc. only. 1.0 metric ton = 1.10 short tons. 1.0 short ton = 0.907 metric ton.

BRAZIL

Cia. Vale do Rio Doce (CVRD) continued work on Brazil's biggest mining project, Carajás, scheduled to start up in

1984. CVRD invested $350,000,000 in 1981, bringing total expenditures on the project to about $619,000,000, or 18.1 percent of its total estimated cost.

Rio Doce borrowed $1,100,000,000 from the National Bank for Economic Development and concluded negotiations to obtain $1,600,000,000 in foreign loans. Iron ore export contracts have been signed for a total of 25,000,000 metric tons per year.

Production of iron ore in Brazil totalled 110,000,000 tons in 1981, close to one-fifth of the value of Brazil's mineral production that year. CVRD remained the largest individual producer of iron ore with an output of 56,200,000 tons of iron ore and pellets, a drop from the 67,600,000 tons produced in 1980.

Brazilian iron ore exports came to 79,700,000 tons, including 53,400,000 tons from CVRD, 11,600,000 tons from Minerações Brasileiras Reunidas S. A., 7,300,000 tons from Ferteco Minercão S. A., 3,800,000 tons from Samarco Mineração S. A., and 2,600,000 tons from S. A. Mineração da Trinidade (Samitri).

Gold production rose to 514,488 ounces in 1981 from 482,330 ounces the year before, despite a temporary halt in operations at Serra Pelada because of security problems. The increase in production was attributed to the higher production capacity at Mineração Ouro Velho's mine, a joint venture between the Anglo American Corporation and the Bozzano Simonsen group. Output was 136,630 ounces of gold compared to 121,291 ounces of gold in 1980.

Brazil became a copper producer in 1981 with the first full year of operations at Indústria e Comércio Caraíba Metais S. A.'s mine in Bahía. Output came to 44,000 tons.

The state-owned company Nuclebras began production of uranium. Capacity is 2,400 tons of ore per day, or 500 tons of yellowcake per year.

Work on three important alumina and aluminum projects continued. Valesul Aluminio S. A.'s 86,000-ton per year aluminum smelter was scheduled for a 1982 start-up. Valesul is owned by CVRD, Shell do Brasil S. A., and Reynolds Metals Company.

Brazilian ore and mineral production in metric tons

Company	1979	1980	1981
Bauxite	1,641,900	4,151,660	3,569,400
Beryl	453	450	450[1]
Copper	5,262	10,000	17,960
Gold[2,5]	43,389	482,330	514,488
Zinc	68,500	70,000	67,120
Columbite-Tantalite	289	290	244[1]
Tungsten, 70 percent WO_3	1,934	1,950	2,000[1]
Chromite	891,543	925,000	260,000[1]
Nickel	2,964	2,540	2,720
Aluminum	448,980	505,940	329,700
Tin, Cassiterite	11,091	10,630	14,000[1]
Manganese Ore	1,981,770	1,249,691	2,100,000[1]
Iron ore	117,502,000	111,800,000	108,281,000
Diamond[3]	83,177	84,000	84,000[1]

1. Estimated. 2. Troy ounces. 3. Metric carats. 1.0 metric ton = 1.10 short tons. 1.0 short ton = 0.907 metric ton. 5. Officially reported.

Brazilian production of iron ore, concentrates, and pellets by companies in long tons

Country	1979	1980	1981
Companhia Vale de Rio Doce	62,995,315	71,312,000	86,913,200
Empresa de Mineração Esperança S.A.	206,300	135,630	98,000
Ferteco Mineração S.A.	6,584,000	2,900,000	8,744,200
Cia. Hispano-Brasileira Pelotização[1]	952,000	1,858,000	1,872,300
Nibrasco[1]	4,090,600	5,305,000	4,279,100
Italo-Brasileira de Pelotização S.A.[1]	1,617,000	2,467,000	2,083,800
Minerções Brasileiras Reunidas S.A.	15,188,100	14,484,100	12,745,342
W. H. Muller S.A.	1,104,600	1,122,900	2,603,672
S. A. Mineração da Trinidade	6,605,300	6,665,500	6,310,300
Samarco Mineração S.A.			
Pellets	3,858,000	3,374,300	3,047,450
Concentrate	516,000	790,460	1,050,310

1. Pellets.

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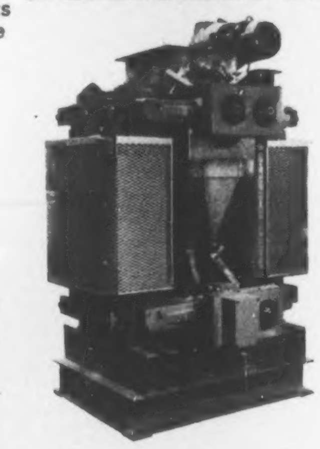

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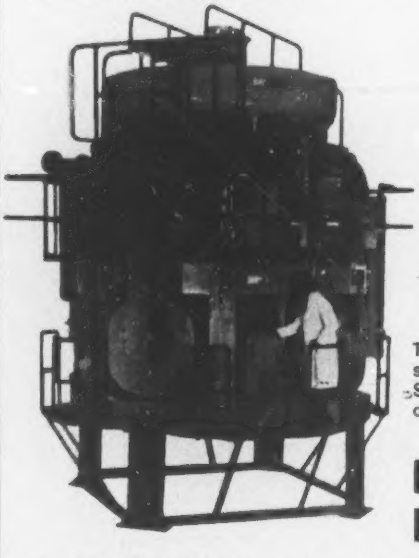

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Aluminio do Maranhão S. A. (Alumar), a joint venture between Alcoa Aluminio do Brasil S. A. and Shell do Brasil, will begin operations in late 1984 or early 1985 at the rate of 500,000 tons of alumina and 100,000 tons of aluminum per year. Aluminio Brasileiro S. A. (Albrás), jointly owned by CVRD and the Nippon Amazon Aluminum Company (Nalco), is scheduled to come on stream in 1985 at an initial rate of 160,000 tons per year.

CHILE

The Chilean mining industry experienced an eventful year in 1981 with the announcement of a new mining code, rumors of amazing copper finds at La Escondida, and the start-up of the El Indio gold mine. Pervasive in all activities was the government's policy to step out of direct control of mining projects and encourage the involvement of foreign and private companies.

The new mining law was announced by Chilean president Augusto Pinochet at the inauguration of the El Indio mine. The law, which encourages foreign investment, sets clear rules for exploration, development, and expropriation. Exploration rights extend a maxiumum of four years, but mining rights have no time limitation. All commodities, except hydrocarbons and strategic minerals, can be mined by foreign-owned companies. Companies are guaranteed compensation in cases of expropriation.

The El Indio mine started operations in late 1981. Annual production capacity was expected to be 321,500 ounces of gold, 1,607,000 ounces of silver, and 12,000 tons of copper. El Indio's reserves are estimated at 3,100,000 metric tons of ore averaging 0.4 ounce gold and 4.5 ounces of silver per ton and 3.5 percent copper. The mine is operated by Compañía Minera El Indio S. A., an 80-percent subsidiary of St. Joe Minerals Corporation, owned by Fluor Corporation.

Copper production at Corporación Nacional del Cobre de Chile's (Codelco) four divisions, which produce 85 percent of Chile's copper output, fell from 902,404 metric tons in 1980 to 893,611 in 1981. The decline was largely because of strikes and a drop in ore grade at the Chuquicamata mine.

Several mine expansions aimed at maintaining copper production were completed by Codelco in 1981 and two major projects are underway for 1982 and 1983. An expansion of Chuquicamata's concentrator to 96,000 tons per day will be finished by mid-1982. The concentrator at the El Teniente mine is scheduled to be expanded by 1983. A tailings dam, Los Leones, was built at the Andina mine in 1981. The capacity of the concentrator at the El Salvador mine was increased by 30 percent.

Production at small and medium mines shot up to 186,700 tons in 1981 from 163,200 tons the year before, bringing Chile's total 1981 copper output to a record-breaking 1,080,000 tons.

Chilean metal and mineral production in metric tons

Commodity	1979	1980	1981
Copper	1,061,000	1,072,000	1,080,310
Molybdenum	13,559	13,668	15,360
Iron ore	1,451,535	8,800,000	7,648,500
Gold[2]	111,400	220,000	297,000
Silver[2]	9,597,000	10,120,000	10,200,000
Manganese	24,000	24,000[1]	24,000[1]
Nitrate	660,000	620,400	620,400[1]
Iodine	2,420	2,500[1]	2,500[1]
Rhenium[3]	1,553,000	1,560,000[1]	1,747,000[1]
Coal	1,250,000	1,200,000[1]	1,400,000[1]
Lead	272	544	272
Zinc	3,682	1,088	998

1. Estimated. 2. Troy ounces. 3. Pounds. N.A. Not available. 1.0 short ton = 0.907 metric ton. 1.0 metric ton = 1.10 short tons.

Chilean production of molybdenum by mines in metric tons

Company	1978	1979	1980	1981
Chuquicamata	8,934	9,258	9,330	9,884
Salvador	1,125	1,212	1,335	1,314
Andina	268	508	691	682
El Teniente	2,777	2,581	2,312	3,480
Totals	13,104	13,559	13,668	15,360

Compañia de Acero del Pacifico S. A. production of iron ore in long tons

Company	1979	1980	1981
Algarrobo	2,807,000	3,178,731[1]	3,067,000[1]
Romeral	3,549,000	4,040,100	3,463,000
Santa Fe	1,051,000	1,055,000	999,000
Totals	7,407,000	8,273,831	7,529,831

1. Pellets

Copper production in Chile in short tons by four big mines and the small and medium sized mines

Year	Chuquicamata	El Salvador	Andina	El Teniente	Total Big Four	Small and Medium	Grand Total
1970	289,297	102,316	6,574	194,418	594,725	166,210	760,935
1971	275,206	93,400	58,942	162,008	628,346	150,700	779,046
1972	257,694	91,182	59,356	209,323	651,875	136,620	788,495
1973	292,032	92,420	61,763	196,006	677,447	121,000	798,447
1974	392,481	87,998	75,218	248,081	839,183	157,208	996,391
1975	335,060	89,430	68,640	257,400	750,530	149,600	900,130
1976	490,050	90,970	62,590	287,870	931,480	174,240	1,105,720
1977	525,629	88,947	64,363	303,191	982,130	145,000	1,127,130
1978	550,700	85,250	52,470	275,660	964,080	210,320	1,174,400
1979	557,900	85,910	51,370	306,020	1,001,200	165,900	1,167,100
1980	562,100	82,600	57,700	292,500	994,900	184,500	1,179,400
1981	520,825	84,388	58,145	321,848	985,206	205,837	1,191,043

Chiquicamata, El Salvador, Andina, and El Teniente are divisions of Corporación del Cobre, largest copper mining company in the world.

A large contributor to the growth in production from medium mines was Exxon Corporation's subsidiary, Compañía Disputada de las Condes. Output at Disputada'a Los Bronces and El Soldado mines rose 34 percent, to 39,173 tons.

Exxon indicated that an expansion at Los Bronces, originally considered to raise production from 8,400 to 80,000 tons of ore per day, may be delayed. Studies on the project will be concluded in late 1982.

Production at Empresa Nacional de Minería's (Enami) Ventanas and Paipote smelters was 98,409 tons of cathodes from its own production and 58,744 tons from other mines. Enami produces about 10 percent of Chile's annual copper output. Enami also owns the Andacollo deposit, which was scheduled to be opened to public bidding next year.

Sociedad Minera Pudahuel's Lo Aguirre mine completed its first full year of production in 1981. Output was 14,345 tons of cathodes.

One of Chile's largest known iron ore deposits, Boquerón Chañar, was scheduled to be opened for bidding in March 1982. Owned by Corporación de Fomento de la Producción (Corfo), the deposit has reserves of 173,000,000 tons of iron ore. The upper layer of the deposit has an average iron ore content of 47 percent; levels between 300 and 800 meters contain 57 percent iron.

Exploration continued at the La Escondida copper-molybdenum deposit, a joint venture between Getty Oil Company Mining (Chile) Inc. and Minera Utah de Chile Inc., a subsidiary of Utah International Inc. Although no official announcements have been made, information to date shows that this deposit could well be developed into a major copper producer.

Conoco Inc. began exploration at its La Mocha deposit in northern Chile. The company reported that samples from drill holes 450 to 500 meters deep indicated strong porphyry copper mineralization. Rio Algom Ltd. conducted advanced exploration at its copper property, Cerro Colorado. Reserves are estimated at 60,000,000 tons of undetermined grade.

COLOMBIA

Work progressed on Colombia's major nickel project, Cerro Matoso, which was to begin operations in mid-1982. The mine will have an annual production of 50,700,000 pounds of ferronickel with an average grade of 37.5 percent Ni.

Reserves are estimated at 20,000,000 metric tons of ore grading an average of 3.28 percent nickel. A total of more than $400,000,000 has been spent over 18 years on development of Cerro Matoso, a joint venture between Instituto de Fomento Industrial, the Colombian development agency (45 percent); Billiton

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MADRID, SPAIN	01/401-20-04*
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Overseas Ltd., the Netherlands-based subsidiary of the Royal Dutch Shell Group (44 percent); and Hanna Mining Company, a United States mining firm (11 percent). Despite the low price of nickel anticipated in 1982, Billiton expected that the mine would operate in the black.

Exploration of several copper deposits continued in 1981. Some 42,000 feet were drilled in 25 holes to delineate the Patascoy porphyry copper deposit, located near the Ecuadorian border. Another 18,000 feet will be drilled in 1982 in preparation for a feasibility study.

More than 35,107 feet were drilled in the Pegadorcito porphyry copper deposits in the departments of Choco and Antioquia. The drilling indicated about 200,000,000 tons assaying between 0.70 and 1.2 percent copper.

Gold production went up in 1981, but silver output fell. Colombia produced 524,550 ounces of gold and 136,054 ounces of silver in 1981, compared to 497,027 ounces of gold and 144,000 ounces of silver.

COSTA RICA

The Santa Clara mine, a joint venture between United Hearne Resources (60 percent) and Canadian Barranca Corporation (40 percent), ended the year 1981 on a promising note. Production was expected to be 350 tons of ore per day in early 1981. Gold is recovered through heap leaching.

Recovery was estimated to be raised by 50 percent as improvements recommended by Witteck Development Inc. of Toronto, Ontario, Canada are implemented. Witteck was hired by United Hearne, the mine operator, to improve gold recovery. Front-end loaders, which more evenly distribute ore for treatment, began to be used late in 1981. Carbon tank circuits were redesigned and new ones added.

A carbon-in-pulp circuit to treat high clay ore, which makes up about 20 percent of the ore body, will be installed in 1982. Additional leaching pads will be added with funds generated from profits. Full capacity of the mine is 2,800 tons per day. Reserves are 4,410,200 tons assaying 0.05 ounce gold per ton.

ECUADOR

Production at Ecuador's major mining operation, Minera Toachi S. A.'s La Plata mine, fell in 1981 and expansion plans have been put off until the metals market recovers. La Plata, located near Santo Domingo de los Colorados, treated 18,000 metric tons of ore in 1981 compared to 21,260 tons in 1980. Output in 1981 (1980 in parenthesis) was: 2,500 (3,550) tons of copper concentrate, 1,720 (1,526) tons of zinc concentrate, and 24 (32) tons of gold-bearing pyrite concentrate. Minera Toachi is 39 percent-owned by the Finnish company, Outokumpu Oy.

Proposals for a new mining law, more favorable to foreign investors, remained in limbo. The new law would involve the establishment of a central mining agency, Corporación de Fomento Minero (Cofemin).

GUATEMALA

Inco Ltd.'s 80 percent-owned subsidiary, Exploraciones y Explotaciones Mineras Izabal S. A. (Exmibal) remained closed through 1981. Cash required for maintaining the care and maintenance status at the nickel mining and smelting plant was $12,000,000. Exmibal officials do not anticipate reopening the plant in the near future.

GUYANA

Output at the Linden plant of Guyana Mining Enterprise Ltd., which controls all bauxite mining in the country, continued its steady decline since the nationalization of the industry in 1971. Output of alumina dropped to 170,000 tons in 1981 compared to 215,000 tons in 1980. Production in 1981 (1980 in parenthesis) was: calcined bauxite, 514,000 (601,000) tons; chemical grade bauxite, 335,000 (428,000) tons; metal grade bauxite, 640,000 (not released) tons.

Guyana is the largest producer of calcined bauxite in the western hemisphere. Guyana Mining plans to raise calcined bauxite production by expanding the East Montgomery and North Dorabec-Arrowcane mines.

Norman Mines Ltd. of Toronto, Canada conducted a drilling program at its gold property on Marudi Mountain and will continue drilling in 1982. In the 1940's Canadian Rupununi Gold Mining Company estimated Marudi Mountain reserves at 230,000 tons assaying 0.34 ounce gold per ton.

Duncan Gold Resources drilled for gold at its Omai gold properties. Drilling to the south and east of areas where Anaconda Copper Company drilled 30 years ago indicated gold values below economic grade.

HONDURAS

Silver recovery at Amax Inc.'s El Mochito mine fell to 1,667,000 ounces in 1981 compared to 1,721,000 ounces in 1980. Lead production dropped from 13,303 tons in 1980 to 12,590 tons. Zinc production remained about the same: 16,197 tons in 1981 and 16,024 tons in 1980. Gold recovery in 1981 was 1,242 ounces. Ore milled rose from 331,000 tons to 343,000 tons.

Further progress was made to expand El Mochito production from 1,200 to 2,500 tons per day. El Mochito has reserves of 6,893,000 tons grading 4.4 ounces of silver, 4.6 percent lead, and 8.8 percent zinc.

MEXICO

The year 1981 was a slow one for Mexican mining. The big companies survived by curtailing exploration and expansion programs.

The only mining related activity that prospered during 1981 was the steel industry. Siderúrgica Lazaro-Cárdenas-Las Truchas (Sicartsa) increased its steel production by 14.2 percent. Some 904,000 tons of molten steel were processed, compared to 792,000 tons in 1980. Construction began on the Hércules-Muzquiz pipeline, which will transport iron concentrate from the Hércules mine to the new pellet plant of Altos Hornos, a distance of about 385 kilometers (239 miles).

Mexico did regain its position as the world's leading silver producer in 1981, with an output of 51,654,829 ounces. Industrias Peñoles S. A. de C. V. had an estimated refined silver production of 35,000,000 ounces; 12,000,000 ounces of the total from its own and affiliated companies' mines. Industrial Minera Mexico S. A., the second largest silver miner in Mexico, produced approximately 7,500,000 ounces.

Peñoles brought its 2,000-ton per day La Minita open pit mine in Michoacán on stream. The mine has reserves of 5,400,000 tons of ore grading 2.2 ounces of silver, 0.25 percent lead, 1.27 percent zinc, and 59 percent combined barium carbonate and barium sulphate. A plant to produce antimony trioxide was also started up during 1981.

The Real de Angeles open pit silver mine was scheduled to start up sometime in 1982. The project is a joint venture between Comisión de Fomento Minero, Minera Frisco S. A. de C. V., and Placer Development Ltd. of Canada. Peñoles' Gochico silver mine was also to begin production in 1982.

Work on the expansion at Compañía Minera de Cananea S. A.'s copper mine continued. Stripping ratios were increased to develop more ore for the higher production levels and site preparation was begun for a new 50,000-ton per day concentrator. Ore production is expected to be raised to 32,000 tons per day in 1982. Capacity is planned to be 82,000 tons per day in 1985.

Mexican production of metals in metric tons

Metals	1979	1980	1981
Gold[1]	190,039	195,986	6,319
Silver[1]	49,407,219	47,342,707	51,654,829
Copper	107,109	175,399	230,466
Lead	173,455	145,549	157,384
Zinc	245,477	238,231	211,629
Iron ore	4,040,989	5,087,361	5,292,609
Manganese	177,359	160,966	208,193
Antimony	2,872	2,176	1,800
Barite	151,162	269,322	317,138
Fluorspar	875,216	916,455	924,854
Coal[2]	6,950,000	6,408,464	6,965,000
Sulphur	2,025,435	2,102,301	2,077,117

1. Troy ounces. 2. Includes all coal mined regardless of use.1.0 kilograms = 32.15 troy ounces. 1.0 short ton = 0.907 metric ton. 1.0 metric ton = 1.10 short tons.

Construction of a flash smelter, the first one to be built in Mexico, was nearly completed at Mexicana de Cobre S. A.'s La Caridad mine. The flash smelter will have a 180,000-ton per year capacity.

Minera Frisco S.A. de C.V.'s Cumobabi mine produced 650,000 pounds of molybdenum in 1981. A leach plant started up in December. Cumobabi, the only molybdenum mine in Mexico, began operations in 1980.

NICARAGUA

The Nicaraguan Institute of Mines reported that a total of 62,000 ounces of gold and 140,000 ounces of silver were produced in 1981. Silver production is expected to fall in 1982 when the La Rosita mine shuts down.

The Nicaraguan government is said to be very interested in increasing production of precious metals to improve Nicaragua's foreign exchange balance. Bulgaria will be conducting geological studies on the El Vesubio mine in 1982, and Sweden is financing geological studies at the El Limón, La Libertad, Topacio, and La Rosita mines.

PANAMA

Cerro Colorado, Panama's enormous undeveloped copper deposit, was placed on care and maintenance status in 1981. Although prefeasibility studies were conducted in 1980 and 1981 for a 120,000 and 50,000-metric ton per day operation, development is being held up for at least several years because of several unresolved problems, including the high cost of supplying power to the project, the lack of a Panamanian labor code, and general indecision within the government following the death of General Omar Torrijos.

The project is owned by the government through Empresa de Cobre Cerro Colorado (Codemin) (51 percent) and Rio Tinto Zinc Corporation (RTZ) (49 percent) of the United Kingdom. The deposit has estimated reserves of 1,300,000,000 tons grading 0.78 percent copper, 0.16 ounce silver, and 0.001 ounce gold per ton.

RTZ purchased its 49 percent share in Cerro Colorado from Texasgulf Inc. of the United State for $5,500,000 in 1980. Texasgulf pulled out of the project because of the relative low grade of the deposit and the weak copper market.

Although development of Cerro Colorado was put off indefinitely, RTZ and Codemin were still considering driving an adit and constructing a pilot plant. RTZ has spent an average of $1,000,000 per month on the project. The hold status of Cerro Colorado should lower RTZ's expenditure by about 90 percent.

PERU

Production slowed in 1981 but many new projects continued to be planned for 1982 to 1984 start ups. A new mining law, developed by the new civilian government, was gradually phased in during the year. The new regulations are encouraging for foreign investment and new project development.

The mining law includes an incremental reduction of the 17.5 percent export tax, which will be reduced to 5 percent by June 1983. Taxes on new projects that mine over 5,000 tons per day may be reduced by up to one-third during the payback period and five years after. Companies may take up to 40 percent of profits in investment credits, which used to be fixed at a given Peruvian sol rate. Private marketing groups may legally compete with Minpeco, the national marketing organization.

Southern Peru Copper Corporation estimated that strikes at the Cuajone and Toquepala mines and at the Ilo smelter caused a production loss of

Peruvian production of metals and minerals in metric tons

Commodity	1979	1980	1981
Iron ore[2,3]	5,358,159	5,600,000	4,033,700
Lead	183,946	175,057	186,700
Zinc	432,000	447,170	496,700
Copper	400,387	363,600	327,600
Antimony	762	773	760[1]
Silver[4]	43,415,000	39,609,700	46,878,000
Molybdenum	1,787	2,800	2,728
Tungsten[5]	215	250	250[1]
Bismuth	527	520	454
Cadmium	190	172	182
Gold[4]	141,700	148,900	220,000
Tellurium	21	21	18[1]
Selenium	18	23	18[1]
Indium[4]	112,036	115,500	100,000[1]

1. Preliminary. 2. Ore, concentrates, and pellets. 3. Long tons. 4. Troy ounces. 5. WO_3 in concentrates. 1.0 short ton = 0.907 metric ton. 1.0 metric ton = 1.10 short tons.

Empresa Minera del Centro del Peru's production of principal metals in short tons

Commodity	1979	1980	1981[1]
Copper[2]	60,918	59,640	54,000
Lead	93,820	90,360	86,850
Zinc, refined	75,172	70,360	74,060
Zinc (export)[3]	126,151	126,000	118,000
Silver[2,4]	25,780,966	23,970,564	25,500,000
Bismuth[5]	1,161,819	1,150,000	1,000,000
Gold[2,4]	43,566	41,000	50,000
Cadmium[5]	418,393	379,000	400,000
Tellurium[5]	46,811	42,000	40,000
Selenium[5]	40,388	41,000	40,000
Antimony[5]	1,052,206	1,100,000	1,000,000
Arsenic[5]	3,119,727	3,000,000	3,100,000
Indium[4]	112,036	110,000	100,000

1. Preliminary. 2. Includes metal content of blister copper produced for export. 3. Zinc contained in export concentrates. 4. Troy ounces. 5. Pounds. 1.0 short ton = 0.907 metric ton. 1.0 metric ton = 1.10 short tons.

45,000 tons of blister copper. Lower mill feed grade also affected production. Production of copper in concentrate was 225,167 tons in 1981 compared to 259,276 tons in 1980.

A feasibility study was conducted on the expansion of the Toquepala mine to increase capacity from 120,000 tons to 160,000 tons per year of blister copper, but the results indicated that an expansion at this time would be uneconomical. Alternate expansion plans were to be examined.

Several new projects were scheduled for start-ups in 1982. Empresa Minera del Centro del Perú's (Centromin) Cobriza mine was planned to be expanded from 2,200 to 10,000 tons per day. According to Compañía Minera Los Montes, a subsidiary of Centromin, the Monterrosas copper mine will begin production at an annual rate of 16,000 tons per year of 25 percent copper concentrate. Centromin's solvent extraction-electrowinning plant in Cerro de Pasco was also scheduled to go on stream in 1982.

Other projects in the works for beyond 1982 include Centromin's Andaychagua lead-zinc-silver mine, which was being reviewed for financing by the Inter-American Development Bank. Start-up date is 1985. The government was also looking for financers for Cerro Verde II and Tintaya projects, both of which are scheduled for start-up in September 1984.

Other projects that are presently scheduled to begin operations within the next five years are Promotoro Bayóvar's planned phosphate plant in northern Peru, the Tambo Grande copper-zinc-silver deposit, and Minero Perú's copper deposit, Antamina.

Southern Peru Copper Corporation's ore, waste, and mineral production at Toquepala and Cuajone in short tons

Commodity	1979	1980	1981
TOQUEPALA			
Total ore and waste mined	44,100,000	47,420,000	30,059,000
Ore milled	16,231,000	15,797,000	13,236,000
Percent copper in ore	0.92	0.92	0.93
Blister copper produced[1]	116,140	82,412	78,323
Molybdenum concentrate produced	2,400	3,196	1,934
CUAJONE			
Total ore and waste mined	70,000,000	67,202,000[1]	55,900,000
Ore milled	16,920,000	16,576,000	15,854,415
Percent copper in ore	1.37	1.15	1.07
Blister copper produced[1]	197,000	211,915[1]	174,331
Molybdenum concentrate produced	N.A.	2,277	3,041

1. Estimated. 1.0 short ton = 0.907 metric ton. 1.0 metric ton = 1.10 short tons. N.A. Not available.

SURINAM

Bauxite, alumina, and aluminum production dropped in Surinam, in spite of the government's goal to raise output. Production in 1981 was (1980 in parenthesis): 4,230,000 (4,903,000) tons of bauxite; 1,260,000 (1,445,000) tons of alumina; and 41,000 (53,500) tons of aluminum.

Exports in 1981 (1980 in parenthesis) came to: 1,126,000 (1,775,000) tons of bauxite, 1,164,000 (1,329,000) tons of alumina, and 32,600 (43,800) tons of aluminum.

The Suriname Aluminum Company (Suralco), wholly-owned by Alcoa of the United States, and Billiton Maatschappij Suriname, N. V., a subsidiary of the Royal Dutch Shell group, are the country's major bauxite producers.

VENEZUELA

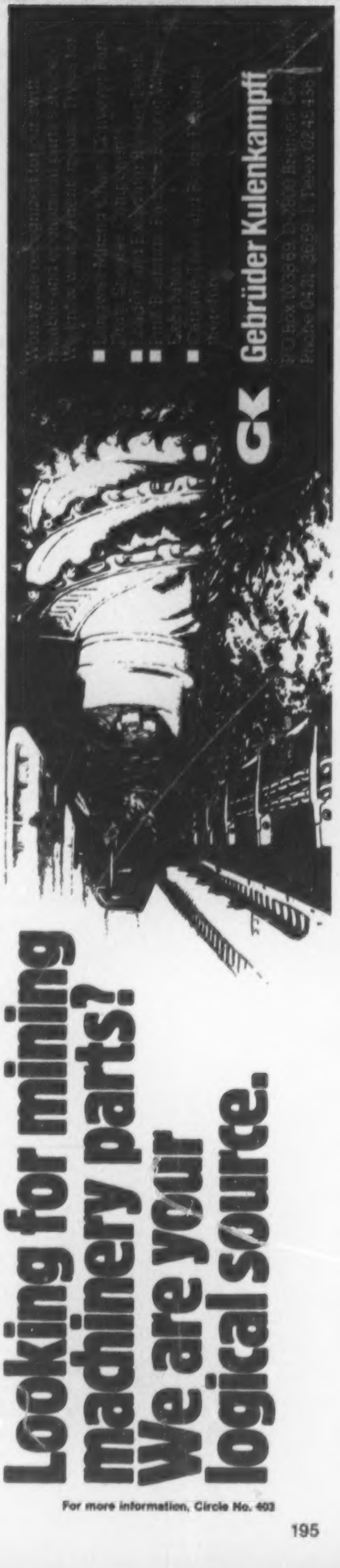
The aluminum industry was hurt badly in 1981. A fire at the Venalum electric smelter of Corporación Venezolana de Guayana damaged about 300 of the 670 smelting pots. Production had reached 160,000 tons in 1980 and an increase to 280,000 tons was planned for 1981, but the fire cut production by about 40 percent. Venalum had sufficient stockpile to fulfill contracts and managed to make a profit in 1981.

Venezuela's second major aluminum producer, Alcasa, lost approximately $15,800,000 in 1981 because of falling aluminum prices.

The present over supply of bauxite and rising cost estimates have delayed C. V. C. Bauxita Venezolana's development of the Los Pijiguaos deposits. The deposits have reserves of approximately 500,000,000 tons of tri-hydrate ore. The bauxite was to supply the 1,000,000-ton per year Inter-Alumina plant at Puerto Ordaz, scheduled to come on stream in 1983 to supply alumina to Venalum and Alcasa.

The year was much brighter for the iron ore industry. C. V. G. Ferrominera Orinoco S. A. produced 14,696,085 metric tons of iron ore, up from 13,970,000 tons in 1980. Sales this year totaled 15,290,000 tons, including 5,387,000 exported to the United States, Venezuela's largest iron ore buyer. Sales to the United States are predicted to drop in 1982 with the fulfillment of a 1,360,000-ton per year contract to Bethlehem Steel Corporation. Domestic sales are forecast to rise following an expansion at the Sidor steel plant. Total sales shouldbe between 15,000,000 and 17,000,000 tons per year through 1985.

Ferrominera Orinoco, Venezuela's national iron ore company, has estimated reserves of 2,000,000,000 tons containing over 55 percent iron and 8,000,000,000 to 10,000,000,000 tons containing under 55 percent iron.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OCEANIA

FIJI

The Empire gold mine of Emperor Gold Mining Company Ltd., is one of the few operating mines to mine and process gold telluride ores. In September, a new telluride recovery circuit and a carbon-in-pulp recovery circuit were placed in operation in the mill. For the year fiscal year June 30, 1980-1981, the mill recovered 27,200 ounces of gold compared with 27,369 ounces in the previous fiscal year. Tons milled were 387,210 compared with 27,360 ounces in the previous fiscal year. The company carried out deep exploration drillng in the Big Mill prospect in the Tavu Basin adjoining the mine.

There were several major gold exploration programs during the year by Pacific Energy Mineral Ltd., Goldfield Mines Ltd., Nullarbor Holdings Ltd., Anglo Pacific Exploration Ltd., Nord (Fiji) Ltd., Consolidated Gold Fields (Fiji) Ltd. and others.

Amax Inc. withdrew from the Namosi porphyry copper exploration group which had discovered three porphyry copper deposits with total reserves of 525,000,000 tons assaying about 0.45 percent copper.

INDONESIA

P.T. Nickel Indonesia was able to keep operating, but at lower than 1980 output, during 1981. At year-end it was only one of two lateritic nickel mines and smelters operating in the world. High grade ore, furnace heads average 2.09 percent nickel during the year and the use of locally generated hydroelectric power which cut energy costs by about 50 percent were of great importance in deeping the mine and smelter in operation. In additions, the use of some coal in the ore dryers and modification of the furnaces cut high cost residual oil consumption by 28 percent.

Indonesian production of metals and minerals in metric tons

Commodity	1980	1981[1]
Tin in concentrate	32,575	34,500
Coal	303,988	402,600
Bauxite	1,249,123	1,200,000
Nickel ore	1,537,442	1,461,000
Ferronickel, nickel content	4,421	3,900
Nickel matte, nickel content	20,300	17,800
Iron sands	74,743	85,811
Copper	53,229	66,150
Gold, ounces	54,642	57,000
Silver, ounces	754,110	687,000

[1] Preliminary and estimated.

Two of the three electric furnaces were in operation to supply the Japanese market for P. T. Inco matte during the year, but at year end plans were underway to shut down one furnace. During the year 1,200,00 tons of ore was mined and furnaced.

Freeport Indonesia, Inc. mined and milled a record high of 3,726,964 tons and 3,571,582 tons of ore respectively. Production figures for 1980 were 3,363,304 and 3,280,654 tons. The increase in mining and milling rates were due to the production from the new Ertsberg East underground block cave mine where 1,187,956 tons or ore were mined. Ore milled assayed 2.10 percent copper, and a recovered content of 0.013 ounce gold and 0.193 ounce silver per ton. Total metal production was 66,150 tons of copper, 46,100 ounces of gold, and 687,000 ounces of silver.

In October the Ertsberg-East mine became operational for financial accounting. New mine development, expansion, and modification of existing facilities cost $87,500,000. The original budget was $101,500,000. At year-end, proved Ertsberg East ore reserves were 43,270,000 tons assaying 2.42 percent copper, 0.029 ounce gold, and 0.41 ounce silver per ton.

Tin production at 34,500 tons was the second highest since the end of World War II. Tin metal production, 35,737 tons, was the a record high. The government compant PT Tambang Tima, operated 19 offshore sea dredges and 13 on land dredges during the year. It also was a partner in the joint venture company, PT Koba Tin, with the Australian company Kajuara Mines which produced 7,250 tons of tin in concentrates.

In January 1982, the first aluminum metal was poured at the Indonesian Aluminum Company's Anshan smelter at Kuala Tanjung. Kaiser Engineers International will do detailed engineering design and procurement for the planned 660,000 annual ton alumina plant with 165,000 tons marked for the Anshan smelter and the rest for export.

A major gold exploration project was underway at the Kelian prospect on Kalimantan Island by CRA Limited. More than 16,500,000 tons assaying 0.026 ounce of gold per ton were indicated. An additional small tonnage of higher grade surface enrichment was also discovered.

NEW CALEDONIA

Societé Metallurgique Le Nickel continued to reduce nickel production during the year in line with its late 1980 announcement and the continuing poor demand for nickel. The Doniambeo smelter produced 48,000 tons of ferronickel compared with 53,297 in 1980. The company announced plans to shut down additional furnaces and set a production target of 38,500 tons for 1982. Exports of nickel ore mined mostly by small producers for export to Japan were also curtailed.

Inco Metals Company and two French partners started mine development at Tiebaghi and were on schedule in mine development and construction of a chromite concentration plant at year end. Production at an initial mining rate of 450 tons of ore per day was scheduled for the second quarter of 1982.

NEW ZEALAND

New Zealand Steel Limited's iron concentrate production from beach sand dredging and magnetic separation declined to 1,956,796 metric tons in 1981 compared with 2,154,889 tons in 1980. The company uses the concentrate in its steel plant at Glenbrook and exports the remainder. The second beach sand miner, Waipipi Iron Sands Limited, expanded its Waverly beach sand mining operations. All magnetic concentrate is exported to Japanese steel mills. Exports in 1981 were about 1,300,000 tons; 1,276,550 tons were exported in 1980.

Darnieri Gold Dredging Limited dug its last gold bearing gravel on the Taramukau River, dismantled the dredge, and moved it to Ngahere on the Grey River where it was being re-erected at year-end 1981.

Mineral Resources (NZ) Limited has proven 15,000,000 tons of 0.14 ounce per ton gold ore amenable to open pit mining near the Martha Hill prospect at Waihi. Mineral Resources is a 50-50 joint venture with Green and McCahill Mining Limited. Amax Exploration (New Zealand) Limited has in interest in Mineral Resources.

PAPUA NEW GUINEA

Higher grade ore and improved recovery in the concentrator at Bougainville Copper Limited's operations in this country contributed to increased production of copper, gold, and silver in 1981. In October, Bougainville set a record in the open pit for total material moved in one week—2,090,000 tons.

Although grade was higher in 1981, as mining progresses, grades will decrease overall. To maintain total metal production constant, higher tonnages of ore will be mined and milled. An eleventh ball mill is scheduled to be commissioned in mid-1982 to handle increased ore tonnages. The twelfth mill will be commissioned about one year later.

At year-end, total reserves at Bougainville were estimated at 800,000,000 metric tons of ore grading 0.40 percent copper and 0.015 ounce gold per ton. (See table on page 200 for complete Bougainville statistics.)

Work has begun on the Ok Tedi copper-gold project which is a joint venture of the government (20 percent), BHP Minerals of Australia Limited (30 percent), Standard Oil Company of Indiana (30 percent), and a West German consortium, Kupferexplorationsgesellschaft GmbH (10 percent). The deposit will be mined in three stages: first, only portions of the gold enriched cap of 34,300,000 tons grading 0.092 ounce gold per ton will be mined; then there will be a period of combined gold, copper, and molybdenum recovery; and finally only copper-molybdenum ore will be milled. The primary deposit underlying the enriched cap has reserves of 377,000,000 tons grading 0.72 percent copper, 0.012 percent molybdenum, and 0.020 ounce gold per ton.

Cost for the first stage, which was begun in 1981, will be $850,000,000. Beginning in 1984 and continuing through 1989, some 12,000 to 15,000 tons of ore per day will be mined and treated. Stages two and three will require $441,000,000 and $143,000,000, respectively.

CRA Limited of Australia reported that surface geological activity increased on the six prospective area at the Frieda River copper prospect. Investigation of geophysical anomalies continued as part of the overall ground geological program. Difficult drilling conditions were encountered at the Nena prospect. A medium size body is indicated, which appears mineralogically complex and metallurgically difficult.

On Misima Island, a 50-50 joint venture between CRA Limited and Placer (PNG) Pty. Ltd., subsidiary of Placer Development Limited, conducted wide spaced drilling which indicated an estimated 25,000,000 metric tons of potentially economic mineralization grading 0.03 to 0.06 ounce gold per ton.

Toward year-end, Nord Resources Corporation and Highlands Energy Corporation (both of the United States) had nearly completed feasibility studies at the chorme-cobalt-nickel depost at the Ramu River, 50 miles southwest of the Madang port. The three-layer laterite deposit has estimated reserves of 225,000,000 tons. The 10-foot thick upper layer contains 107,000,000 tons of sandy, clay-type material material containing about 9 percent metallurgical grade chromite. The second layer, 9-foot thick limonitic laterite, has reserves of 81,500,000 tons of material grading 1.12 percent nickel, 0.16 percent cobalt, and 6.0 percent chromite.

PHILIPPINES

Several production and mining tonnage records were set by copper mining companies during 1981. However, due to the low prices for metals several large producers lost money or barely broke even.

Of the total gold and silver production of Atlas Consolidated, 81,475 ounces of gold and 50,030 ounces of silver were produced at the company's Masbate gold mine. Typhoons at both mines caused loss of production.

With increased local power from a new Diesel electric generator, Marinduque Mining and Industrial Corporation raised its Sipalay mining and milling rate with a subsequent increase in copper production to 29,259 tons of copper compared with 19,114 tons in 1980. Ore milled totalled 6,874,837 tons compared with 2,317,190 tons. A total of 16,026,274 tons of waste were stripped.

Marcopper Mining Corporation mined and milled record tonnages during the year. Mining rate was increased by using a new electric P&H 21 cubic yard shovel. Softer ore was milled

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Bougainville Copper Limited's operating results

Category	1979	1980	1981
Tons waste stripped	43,780,000	46,420,000	44,000,000
Tons ore milled	39,820,000	41,360,000	41,800,000
Average tons per day	109,096	113,315	114,521
Percent copper in feed	0.55	0.46	0.51
Total copper, tons	219,010	190,256	213,180
Ounce gold per ton	0.022	0.015	0.0171
Total gold, ounces	876,040	620,400	714,780
Ounce silver per ton	0.050	0.043	0.045
Total silver, ounces	1,959,350	1,764,115	1,878,910
Copper recovery, percent	85.78	86.04	85.14
Gold recovery, percent	67.7	66.5	75.6
Silver recovery, percent	72.1	66.6	71.9
Concentrate recovered, tons	643,161	561,437	633,600
Concentrate recovered: ton per ton ore milled	0.016	0.014	0.015
Copper in concentrate, percent	29.21	28.8	28.65
Gold in concentrates, ounces per ton	1.08	0.88	0.85
Silver in concentrate, ounces per ton	2.45	2.32	2.13
Total copper recovered, tons	187,867	163,694	181,500
Total gold recovered, ounces	633,451	451,706	540,120
Total silver recovered, ounces	1,435,176	1,184,920	1,350,300

so that tonnage was greater and more copper was produced despite a lower recovery due to milling of partially oxidized ore.

Benguet Corporation operated the open pit copper-gold Dizon mine and the underground gold vein mines in the Baguio district.

Production of both nickel and cobalt was lower than in 1980 by Marinduque Mining and Industrial Corporation. The record production was 31,046 metric tons of nickel in 1978; it was 25,382 tons in 1980; and dropped to 21,456 tons in 1981. Cobalt is a byproduct, so production of 999 metric tons in 1981 was down from 1,332 tons in 1980. Marinduque operates an open pit lateritic nickel mine on Nonoc Island and dries the ore before treating it by the Sherritt Gordon pro-

Philippine production of metals and minerals in metric tons

Mineral	1979	1980	1981
Gold[1]	530,684	654,405	752,561
Silver[1]	1,804,226	1,920,046	1,969,654
Copper	297,036	305,687	300,650
Cobalt	1,370	1,332	999
Chromite			
Refractory	436,633	340,460	269,579
Metallurgical[2]	96,247	92,802	90,914
Iron ore	2,957	0	0
Lead	1,949	1,782	1,015
Zinc	9,674	7,070	5,233
Molybdenum	118	88	80
Pyrite cinders	100,909	123,955	97,872
Manganese ores	4,997	500[3]	0[3]
Nickel, metal	21,479	25,382	21,456
Cement[4]	138,712,476	145,000,000[3]	135,000,000[3]
Coal	367,323	400,000[3]	425,000[3]
Barite	10,140	5,560	2,135

1. Fine ounces. 2. Concentrate plus ore. 3. Estimated. 4. Bags. 1.0 short ton = 0.907 metric ton. 1.0 metric ton = 1.10 short tons.

Philippine production of copper in metric tons

Company	1979	1980	1981
Acoje Mining Co. Inc.	3,181	3,121	2,563
Atlas Consolidated Mining & Development Corp.	125,257	126,049	138,972
Baguio Gold Mining Co.	4,781	6,064	5,116
Benguet Corporation Dizon Copper	—	25,189	28,083
Benguet Exploration, Inc.	138	127	109
Black Mountain, Inc.	3,203	2,991	2,557
CDCP Mining Co.	19,641	20,404	12,244
Consolidated Mines Ltd.	7,546	6,760	0
Lepanto Consolidated Mining Co.	18,646	15,231	22,695
Marcopper Mining Corp.	44,472	34,456	36,277
Marinduque Mining & Industrial Corp.			
Bagacay Copper Project Sipalay Copper Project	30,210	19,464	26,613
Philex Mining Corp.	22,369	22,081	22,695
Sabena Mining Co.	6,144	9,589	176
Western Minolco Corp.	11,577	13,892	9,781
Zambales Base Metals, Inc.	405	286	138
Totals	297,579	305,687	300,650

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cess. Operations continued at a loss and additional govermental financing was necessary to maintain operations.

There is one miner and shipper of nickel ore on Palawan Island, Rio Tuba Mining Company, which exported 345,310 dry metric tons of ore to Japan in 1981.

One of the world's largest refactory grade chromite mines in the world, Masinloc of Consolidated Mines Inc.is operated under contract by Benguet Corporation. Shipments of concentrates were lower than in 1980 at 269,579 metric tons compred with 340,460 a year earlier.

There was little change in production of metallugical chromite conentrate by Acoje Mining Company at 90,914 metric tons compared with 92,802 tons in 1980.

Philippine gold production in ounces

Company	1979	1980	1981
Apex Exploration & Mining Company, Inc.	20,483	24,823	39,00
Atlas Consolidated Mining & Development Corp.	96,325	150,282	194,019
Atok-Big Wedge Mining Company, Inc.	2,707	0	0
Baguio Gold Mining Co.	9,542	11,670	9,968
Benguet Corporation	86,901	183,001	206,421
Benguet Exploration, Inc.	12,596	11,944	12,049
Black Mountain, Inc.	2,640	2,865	1,790
CDCP Mining Co.	3,077	3,774	2,482
Itogon-Suyoc Mines, Inc.	7,034	8,772	11,842
Lepanto Consolidated Mining Co.	76,134	58,166	61,437
Manila Mining Co.	958	4,630	4,827
Marcopper Mining Corp.	52,003	25,958	30,069
Marinduque Mining & Industrial Corporation	5,224	4,543	6,933
Philex Mining Corporation	125,842	116,476	122,900
Sabena Mining Co.	4,437	7,005	4,457
Vulcan Mining Co.	6,800	6,774	13,096
Western Minolco Corporation	20,688	23,399	18,471
Totals	586,936	547,344	752,561

Individual company figures are rounded.

Philippine silver production in ounces

Company	1979	1980	1981
Apex Exploration & Mining Company, Inc.	13,628	14,162	17,336
Atlas Consolidated Mining & Development Corp.	404,341	415,346	536,680
Atok-Big Wedge Mining Co., Inc.	1,674	0	0
Baguio Gold Mining Co.	33,873	40,683	32,873
Benguet Corporation	112,353	304,997	332,849
Benguet Exploration, Inc.	61,747	73,697	64,427
Black Mountain, Inc.	14,477	21,524	14,778
CDCP Mining Co.	128,163	132,612	85,634
Itogon-Suyoc Mines, Inc.	3,482	3,678	1,050
Lepanto Consolidated Mining Co.	289,080	238,728	248,886
Manila Mining Co.	469	1,823	1,350
Marcopper Mining Corp.	242,787	188,283	188,430
Merinduque	237,537	171,585	202,828
Philex Mining Corporation	143,804	135,557	143,000
Sabena Mining Co.	29,716	42,531	886
Vulcan Mining Co.	7,996	7,944	7,842
Western Minolco Corporation	82,783	98,463	75,221
Totals	1,819,605	1,920,005	1,969,670

Company figures are rounded. N.A. Not available.

WORLDWIDE SURVEY

UNITED STATES

ALASKA

Preliminary figures indicate that gold production rose from 9,826 ounces in 1980 to 18,000 ounces in 1981, reversing the decline in gold output of the past 4 years.

Gold and silver were produced by an estimated 400 placer operations and several small lode mines. Alaska Gold Company operated its dredges number 5 and 6, near Nome, and reactivated the Hogatza River dredge. Northland Gold Dredging operated the 6-cubic-foot dredge it rebuilt last year. Several smaller capacity bucketline dredges operated in the Seward Peninsula and Kuskokwin River Regions. Hanson Properties operated its platinum placer dredge south of Goodnews Bay. Other mechanized placer mines used various types of equipment in at least 21 of the state's 67 mining districts. The Grant, Mikado, and Silver Star lode mines produced gold and silver ores.

Minerals exploration expenditures were estimated at about $100,000,000, a large increase over 1980. There were about 26,000 new mining claims recorded as of November 1981, compared to 20,000 in 1980. Major mining companies continued exploration on their base and precious metals claims in the DeLong Mountains, Brooks Range, Seward Peninsula, Alaska Range, Tanana Uplands, Southeastern Alaska, and other areas.

Surface diamond drilling continued and several thousand feet of underground workings were driven in preparation for bulk sampling at the Quartz Hill deposit, one of the most important known reserves of molydenum in the United States.

Alaska also produced gemstones (coral, jade, and soapstone) silver, placer tin concentrates, and lode tungsten concentrates.

ARIZONA

Copper production accounted for 75 percent of a record high $2,500,000,000 nonfuel mineral production in this state in 1981, as the industry recovered from the low production level caused by the 5-month long copper strike in 1980. Copper production exceeded a previous high in tonnage, but lower copper prices prevented the value of that output from achieving the high point reached in 1979. Molybdenum, silver, and gold, principal byproducts of copper production, also dropped in value of output because of the decline in the price of metals. Arizona ranks first in copper production in the United States, producing an estimated 1,127,346 metric tons valued at $1,915,000,000 in 1981.

Growing stocks of copper and falling metal prices led to reduced work schedules, layoffs, and mine closures at various Arizona copper mines. Early in the year, Phelps Dodge Corporation closed its Metcalf open pit and reduced copper output at the Morenci property by 8 percent; later in 1981, the company announced another reduction in copper output, reduced schedules and layoffs for 1982. In December, Duval Corporation shut down its Esperanza, Sierrita, and Mineral Park (Ithaca Peak) operations for 3 months, idling almost 2,000 workers. Asarco Inc. scheduled closure of its Silver Bell property until market conditions improved.

Nevertheless, copper companies continued to plan and to modernize for increased productivity. Cities Service Company completed a second solvent extraction-electrowinning plant at its Miami operation; Cyprus Bagdad Copper Company announced expansion of its Bagdad copper operation from 40,000 tons per day to 50,000 tons by year end; and Inspiration Consolidated Copper Company revealed plans for a 10-year, $450,000,000 modernization and expansion program. In addition to the above projects, installation of pollution control equipment was scheduled or underway at the Inspiration, Morenci, Ajo, and Hayden smelters.

ARKANSAS

Nonfuel mineral production in this state during 1981 was valued at $302,700,000, a slight increase over the previous year. Arkansas continued its role as a major producer of barite, bauxite, bromine, and vanadium. Bauxite production was 1,347,746 tons, valued at $18,951,000.

Reynolds Metals Company temporarily phased out its mining operations at Bauxite and shut down several potlines at Jones Mill; the closing left the company operating at about 67 percent of its North American aluminum capacity. Union Carbide Corporation resumed production of vanadium oxides at Wilson Springs and is developing sites a mile northwest of its main offices in Garland County. Highland Gypsum Company began mining operations after a 2-year closing; the area was formerly operated by Dulin Bauxite Company.

Milchem Incorporated continued constructing a barite processing plant, mine, and other facilities and hopes to begin mining in August of 1982. The barite ore is not of especially high grade, and the life of the plant has been estimated at 10 years.

CALIFORNIA

The production value of California's nonfuel mineral output in 1981 was an estimated $1,900,000,000, a slight drop from previous years. As in prior years, nonmetallics accounted

United States mine production of metals and minerals

Commodity	1977	1978	1979	1980	1981[1]
Gold[2]	1,100,347	965,084	970,000	951,348	1,303,973
Silver[2]	38,165,703	39,400,000	38,100,000	31,326,797	37,560,299
Copper[3]	1,364,000	1,358,000	1,444,000	1,109,239	1,448,428
Lead[3]	537,499	551,000	450,432	604,432	488,482
Zinc[3]	448,685	302,699	294,693	388,348	335,800
Coal[3]					
Anthracite	6,200,000	6,445,000	6,200,000	6,200,000	6,000,000
Other ranks	685,000,000	617,000,000	763,800,000	834,400,000	832,000,000
Asbestos[3]	93,000	93,000	93,000	80,000	81,000
Barite[3]	1,494,000	2,170,000	2,112,000	2,245,000	2,400,000
Boron[3]	735,000	778436,000	799,000	783,000	750,000
Bauxite[4]	1,981,209	1,669,000	1,821,000	1,550,000	1,486,000
Nickel[3]	12,958	13,509	15,065	14,653	15,600
Vanadium[5]	13,008,000	8,544,000	11,040,000	9,612,000	10,600,000
Magnesium[3]	126,016	162,000	170,000	165,000	162,000
Sulphur[4,6]	10,557,577	11,180,000	11,470,000	11,484,000	11,594,000
Fluorspar conc.[3]	169,000	129,000	109,000	93,099	115,100
Tungsten[5]	6,022,000	6,901,000	6,646,000	6,036,000	7,000,000
Iron ore					
and conc.[4]	55,750,000	80,700,000	85,700,000	69,600,000	74,307,000
Molybdenum[5]	122,408,000	132,000,482	143,967,000	150,686,000	137,303,000
Phosphate rock[3]	47,256,000	50,037,000	51,611,000	59,840,000	58,190,000
Soda ash					
natural[3]	8,039,587	8,290,000	8,252,000	8,200,000	8,281,495
Potash, K_2O[3]	2,229,000	2,268,000	2,464,000	2,239,000	2,150,000
Uranium oxide[3]	14,600	15,000	18,730	21,850	19,140
Selenium[5]	499,475	508,636	587,118	310,588	5554548
Cadmium[5]	4,409,794	3,805,350	3,231,128	3,479,490	3,479,755
Cement[1,3]	75,823,596	82,000,000	84,800,000	75,730,707	71,700,000
Aluminum[3,8]	4,538,710	4,803,777	5,023,098	5,129,699	4,948,000
Mercury[9]	28,244	24,163	29,519	30,657	27,933

1. Preliminary, U.S. Bureau of Mines figures. 2. Fine ounces. 3. Short tons. 4. Long tons. 5. Pounds. 6. Frasch plus other. 8. Includes output from imported bauxite. 9. Flasks. N.A. Not available.

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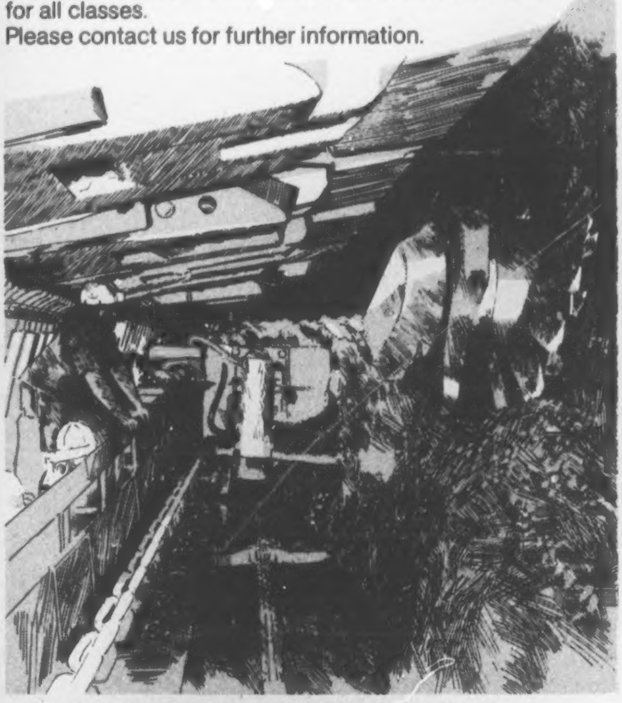

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for over 90 percent of this total. Cement, boron minerals, and sand and gravel were the leading commodities; iron ore was the leading metallic mineral.

Preliminary figures indicate that gold production in the state during 1981 nearly doubled that of 1980. In 1981, some 6,700 ounces of gold, with a value of $3,100,000, were produced, compared with 3,651 ounces, valued at $2,236,000, for the previous year. Placer Service Corporation's Yuba Dredge Number 21, after years of inactivity, began full-scale dredging operations in September. The dredge was reconstructed at a cost of $10,000,000, and can dig to 140 feet below water level. In 1982, the No. 17 Dredge is to be renovated at a cost of $7,000,000. The company estimates that gold production from these operation will approach 20,000 to 25,000 ounces annually.

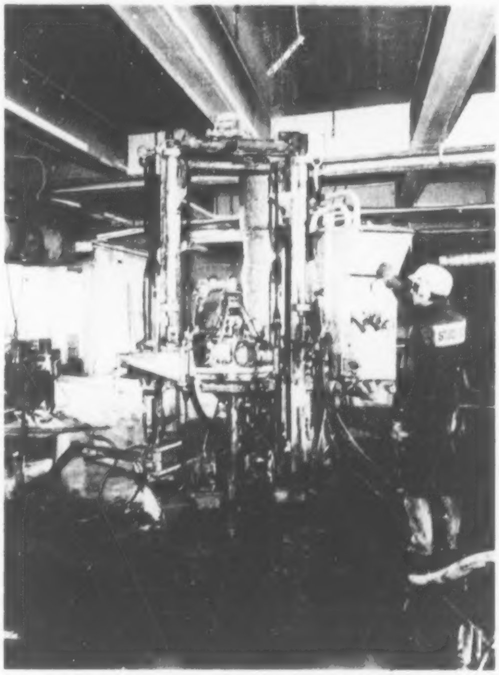
Gold reserve figures have been revised upward at Homestake Mining Company's McLaughlin mine project in Napa County. The deposit may contain nearly 3,500,000 ounces of gold and has passed from the exploration stage to development. Estimates are that capitalization costs will exceed $200,000,000.

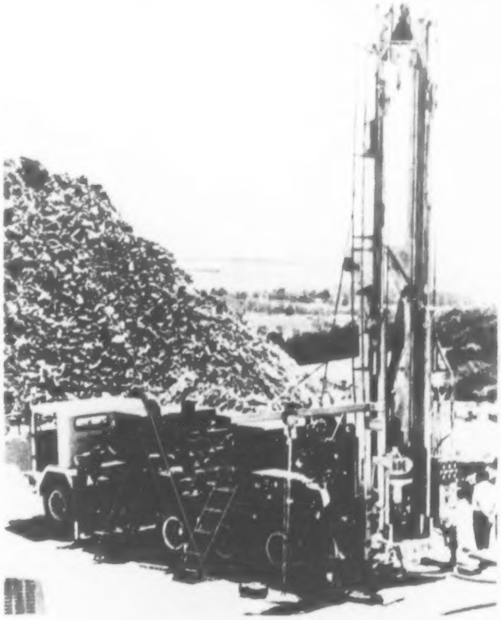
Kaiser Steel Corporation announced in November that it would shut down its primary steel making operation in Fontana and its Eagle Mountain mine, reducing its work force at the two facilities from 7,000 to 4,000 employees over the next two to four years; the company was unable to find a buyer for the complex.

With the expiration of the moratorium on new mining

United States iron ore, concentrate, and pellet shipments by companies and mines in gross tons

Company/Mine	1977	1978	1979	1980	1981
Bethlehem Mines Corporation					
Grace[1]	560,917	—	—	—	—
CF&I Steel Corporation					
Cedar City District[4]	901,610	802,836	730,588	708,333	71,905
Sunrise[1]	372,603	439,495	432,680	245,636	0
City Service Company					
Copperhill[5]	325,000	364,595	N.A.	N.A.	N.A.
Cleveland-Cliffs Iron Company					
Canisteo	1,121,720	612,691	586,331	720,767	956,994
Empire[2]	3,943,086	5,758,339	5,453,060	4,782,433	6,619,845[1]
Republic[3]	2,134,864	4,103,349	3,573,069	1,429,583	1,228,938
Pioneer[4]	766,923	1,439,823	1,127,305	132,600	52,726
Mather	71,865	97,500	82,357	22,656	—
Tilden[2]	2,800,483	3,879,793	4,658,043	7,424,951	6,263,903
Erie Mining Company (Pickands Mather & Co.)					
Erie[2]	3,500,827	9,128,000	9,472,070	6,102,200	15,122,406
Eveleth Taconite Company					
Fairlane[1]	2,761,147	4,803,574	5,594,171	5,334,675	7,649,257
Hibbing Taconite Company (Pickands Mather & Co.)					
Hibbing[2]	2,283,139	5,313,561	6,232,930	6,402,658	7,154,263
Hanna Mining Company					
Butler[4]	1,771,331	2,481,615	2,434,291	1,662,763	2,200,000
National[5]	2,651,871	4,836,427	5,587,013	2,788,237	2,665,208
Pierce	49,684	—	—	—	—
Whitney	213,081	181,305	283,398	13,400	—
Lauretta	10,643	—	—	—	—
Groveland[5]	2,218,301	2,043,153	2,087,269	1,712,854	N.A.
Carmi	7,206	—	—	—	—
Inland Steel Mining Company					
Sherwood	212,767	147,921	243,944	20,822	0
Minorca[2]	206,000	1,800,000	2,143,910	1,476,745	2,445,000
Jackson County Iron Company					
Black River Falls[2]	667,623	649,635	735,522	679,151	853,457
Jones & Laughlin Steel Corporation					
McKinley	907,567	973,700	677,575	} —	463,136
Benson Mines	730,044	—	—	} /27,000	463,136
Lind Greenway	632,982	—	—	} —	—
Hill Annex	862,074	C87,746	52,869		
Kaiser Steel Corporation					
Eagle Mountain	1,804,220[6]	1,834,342[3]	2,088,290[6]	1,191,491[3]	1,175,132
	872,798[6]	669,848[6]	800,720[6]	842,588[6]	643,661
Total	2,677,018	2,504,196	2,889,010	2,034,079	2,349,410





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tana and its Eagle Mountain mine, reducing its work force at the two facilities from 7,000 to 4,000 employees over the next two to four years; the company was unable to find a buyer for the complex.

With the expiration of the moratorium on new mining operations in Death Valley National Monument, numerous new and revised mining operating plans were approved, mostly for boron.

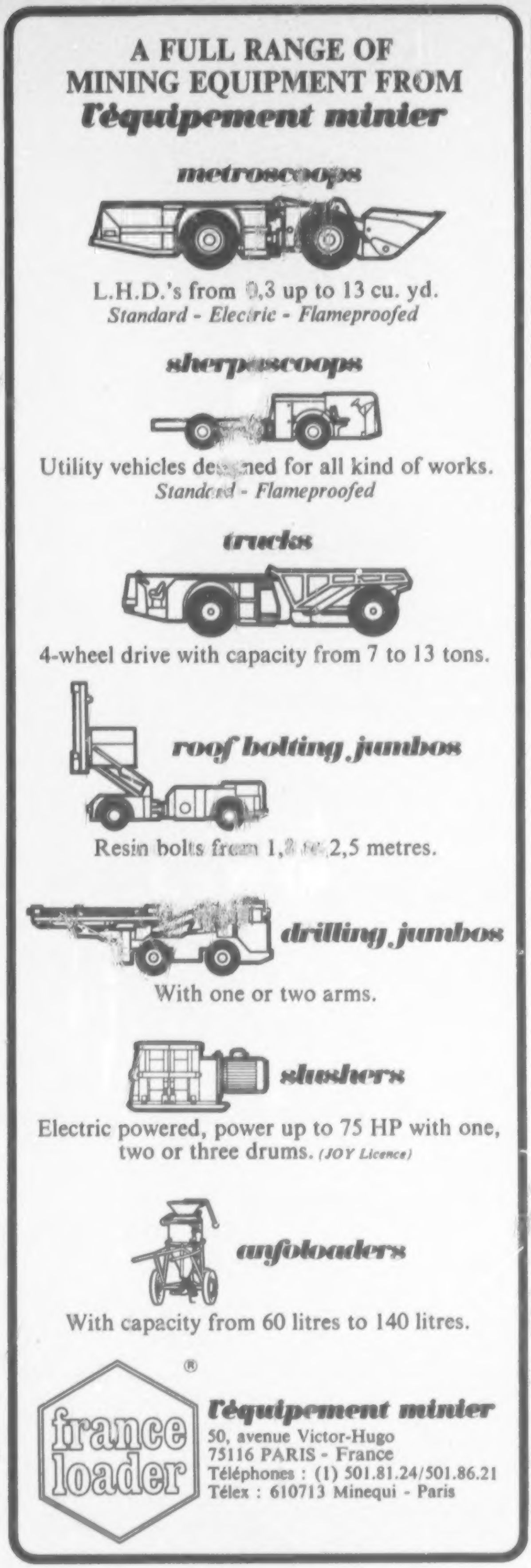
COLORADO

The value of nonfuel mineral production in Colorado in 1981 was estimated $912,800,000. This, the first decline in value of mineral ouput in more than a decade, resulted from lower gold and silver prices and a decline in both price and output of molybdenum. Molybdenum production was estimated at 76,100,000 pounds, valued at $583,687,000, compared with 101,799,000 pounds valued at $908,886,000 for 1980.

Climax Molybdenum Company experienced a deteriorating market in 1981 that resulted in a decline in market share (normally 45 percent) and an increase in inventory from a normal 4-month to about a 9-month supply. The company ceased new hiring at its two Colorado mines, Climax and Henderson, and by the beginning of 1982, had announced a cut

Company/Mine	1977	1978	1979	1980	1981
Meramec Mining Company					
Pea Ridge[2]	1,050,000	—	—	—	1,100,000
NL Industries, Inc.					
Tehawus[3]	200,000	365,000	N.A.	—	—
Nevada-Barth Corporation					
Barth[1]	114,573	N.A.	N.A.	N.A.	N.A.
Pilot Knob Pellet Company					
Iron Mountain[2]	761,960	590,160	689,693	—	—
Pittsburgh Pacific Company					
Dunwoody	10,385	—	—	—	—
Embarrass	2,247	—	—	—	—
Neville	596	8,972	—	—	—
Niles	122,959	1,043	—	—	10,689
Zeno	37,676	149,800	124,569	77,079	107,461
Donora	121,817	17,472	—	—	—
Knox Extension	14,186	19,560	12,406	—	—
Connie	—	75,373	94,806	49,440	59,986
Pillsbury Brown	60,664	1,331	—	—	—
Pittsburgh Pacific	—	18,807	—	33,907	42,706
Wyoming Annex	34,536	1,660	35,016	68,741	47,596
Algoma	25,648	76,450	—	29,147	17,150
Rochleau Annex	33,526	67,252	9,275	2975	37,980
South Sauntry	—	—	104,191	59,880	29,896
Sliver	—	—	3,277	—	1,011
Gilbert	N.A.	N.A.	N.A.	N.A.	2,836
Monroe	N.A.	N.A.	N.A.	N.A.	13,853
South Tener	N.A.	N.A.	N.A.	N.A.	1,497
Reserve Mining Company					
E.W. Davis[2]	5,054,700	9,149,029	9,500,000	4,399,070.	7,597,016
Rhude & Fryberger Inc.					
Gross-Nelson	26,569	74,000	25,719	N.A	19,524
Hull-Rust-Day	3,811	34,546	9,704	N.A.	15,416
Rana	45,497	—	—	N.A.	295
Sharon	—	26,732	134,495	N.A.	71,230
Wabigon	254,903	102,978	1,152	N.A.	7,489
Snyder Mining Company					
Kosmerl	50,073	114,165	N.A.	N.A.	N.A.
Standard Slag Co.					
Beck[3]	10,400	—	N.A.	N.A.	N.A.
United States Steel Corporation					
Minntac[2]	7,426,494	12,377,579	16,456,390	14,411,700	12,525,210
Sherman	582,659	1,073,606	565,805	203,770	194,000
Rochleau	347,156	144,713	261,077	—	—
Arcturus	—	—	755,780	388,268	741,800
Plummer	1,850,000	1,173,500	—	—	—
Atlantic City[2,4]	1,853,000	1,710,000	1,639,000	1,693,000	1,744,000
Desert Mound[6]	612,000	811,000	387,000	245,000	640,000
Utah International Inc.					
Iron Springs	705,205	704,556	678,044	511,000	

1. Preliminary. 2. Pellets. 3. Long Tons. 4. Net tons. 5. Ore. 6. Concentrate. N.A. Not available.



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in production of 25 to 30 percent. The Mt. Emmons molybdenum project was postponed.

In October, the New Jersey Zinc Company closed down its Eagle mine, which for nearly 100 years has been the state's largest producer of zinc. With the decline in zinc prices in 1977, the operation was restricted to mining silver and gold ore. Falling precious metal prices forced termination of operations at the famous mine.

Interest in redeveloping and reevaluating old gold and silver properties remained strong although no significant increase in production from reconditioned or new mines was apparent. Again, the decline in gold and silver prices during the year affected activity in these metals.

Lower prices for both vanadium and uranium, which are coproducts in some Colorado ores, led to the closure of several vanadium-uranium mines in the state. Union Carbide Corporation's Uravan mill was closed for about 6 months of the year and reopened to service existing contracts. Cotter Corporation's mill at Canon City remained in operation, but with continuing environmental controversy. Homestake Mining Company indefinitely delayed construction of a mill at its Pitch mine project and scaled down operations at that mine.

FLORIDA

The value of nonfuel minerals produced in Florida in 1981 increased nearly 9 percent to an estimated $1,600,000,000. Crushed stone, cement, and phosphate rock were the major commodities produced and accounted for the major portion of the increase in value for 1981.

Phosphate production was at a high level early in the year but decreased later in 1981 as demand fell off. Inventories increased to high levels, resulting in reduced operation levels and temporary closure of some mines and plants. However, nearly all companies were involved in expansion of new developments, maintaining that cyclical variations are common in the industry and forecasting increases in demand.

Associated Minerals Consolidated continued modification and expansion at its heavy minerals project at Green Cove Springs. Modifications centered on the wet mill, dry mill, and dredging operations, with full production scheduled for early 1982. Tentative plans call for further enlargement of the mine, if research now underway is successful.

IDAHO

This state's 1981 nonfuel mineral production value fell to $420,000,000. Lower metal prices caused the decline and slowed development of mines in the state. The quantity of silver produced increased over 1980 production, but the average price of silver went down, giving 1981's production figure of 16,265,000 ounces a value of $178,915,000. The previous year's figures show that 1980's 13,695,000 ounces had a value of $282,663,000.

Lower metal prices caused, in part, the August announcement of the closing of the Bunker Hill Company. Closure would affect smelting, refining, and acid plant operations at Kellogg; the mine closed early in 1982.

Two important mergers were completed in 1981. Hecla Mining Company took over Day Mines Incorporated and formed it into a wholly-owned subsidiary. Sunshine Mining Company acquired four smaller firms that had land holdings around the Sunshine mine: Sunshine Consolidated Inc., Big Creek Apex Mining Company, Silver Syndicate, Inc. and Silver Dollar Mining Company.

Cyprus Mining Corporation was ahead of schedule in developing its proposed 25,000 ton-per-day Thompson Creek molybdenum mine. Noranda Mining Incorporated continued development work at the $250,000,000 Blackbird cobalt-copper project. Early in the year, the company announced plans to build a $50,000,000 cobalt refinery; this decision was later put on hold. Pre-production costs of $10,000,000 were estimated

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by Superior Oil at its new Stibnite gold property. Construction was under way by the summer of 1981. Silver King Mines Incorporated announced it would close its Copper Cliffs mine at year-end because of declining copper and silver prices.

MICHIGAN

The estimated value of nonfuel mineral production in 1981 was $1,500,000,000. Value dropped for the second consecutive year becasue of the faltering economy. Iron ore contributed the greatest amount of value to production. Last year, some 14,876,000 long tons of iron ore were produced having a value of $653,679,000.

The depressed state of the steel industry led to iron mine closings on the Marquette Range in the Upper Peninsula, as producers adjusted inventories to meet weakened demand. Most steel mills were operating below capacity, although shipments of steel on the national level increased slightly from the previous year.

Copper Range Company began construction of a $78,000,000 electrolytic refinery at its White Pine Copper complex. The facility is slated for completion in October 1982.

Exploratory work was essentially completed on the Ropes gold mine, and the mine placed under care and maintenance awaiting approval of Callahan Mining Corporation's board of directors to proceed with the $20,000,000 project.

MINNESOTA

Nonfuel mineral production in this state was valued at $2,112,500,000, an increase of 19 percent over 1980 and 2 percent of the previous record high in 1979, according to preliminary statistics. Minnesota continued to lead the United States in the production of iron ore, with 49,568,000 long tons in 1981.

Due to a continuing weak demand for steel nationally, the state's taconite industry was adversely affected, experiencing production cutbacks and temporary closures at many of the facilities. Taconite pellet shipments during the year were at a reduced level, approximately 25 perconet below the combined rated production capacity of the state's plants.

MISSOURI

Missouri was again the United States' top lead producer, yielding some 436,392 tons of lead, valued at $348,000,000.

St. Joe Lead Company continued to develop Viburnum No. 35 mine and Cominco American Incorporated and Dresser Industries, Incorporated continued development of the lead/zinc Magmont West Mine. Noranda Mines Ltd.'s expansion of its aluminum reduction plant at New Madrid was completed in August; capacity was increased by more than 60 percent. Pea Ridge Iron Ore Company's mine was the only underground source of magnetite in the United States.

The United States Forest Service continued to process and Environmental Assessment of the Irish wilderness area, which is south of the Viburnum Trend. If the Assessment is favorable toward exploration objectives, restricted mineral prospecting will be permitted in the area. Even if the area is designated a Federal Wilderness area, mining will not necessarily be forbidden, but it will be strictly supervised and controlled.

MONTANA

According to the U. S. Bureau of Mines, estimated value of nonfuel mineral production in Montana during 1981 was $301,000,000. Metals accounted for 58 percent of the estimated total. Copper continued to be the principal commodity; preliminary figures indicate that production in 1981 was 68,324 tons valued at $116,000,000. Production in 1980 was 41,600 tons valued at $85,236,000.

Anaconda Copper Company continued to have a strong

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impact on the state's economy. The company reduced its work force in the Butte area when output from the Berkely Pit declined from 50,000 to 44,000 tons of ore per day. It activated its concentrator in Anaconda to recover copper from slag and placed an $8,000,000 molybdenum circuit onstream at the Weed Concentrator. Anaconda also applied for an operating permit for its proposed platinum-palladium mine and obtained a waste-dump permit for its Berkely pit operation. In January 1981, the first shipment of copper concentrates from the Weed Concentrator, formerly smelted at the now defunct Great Falls operation, was sent to Japan.

Other significant developments in the state include Asarco Inc.'s Troy project, a copper-silver mine-mill complex going onstream with full capacity expected during late 1981. Placer Amax Incorporated obtained an operating permit for its Golden Sunlight gold property. Construction of the mine-mill complex was scheduled to commence in April 1982.

Approximately 10 heap-leach operations were either producing or being researched. Landusky Mining Company and Zortman Mining Company, the largest of the heap-leach operations, reportedly produced in excess of 40,000 ounces of gold and 90,000 ounces of silver.

Precious metals were being sought throughout the state, with emphasis on former producing areas. Placer activities were noted in Lewis and Clark, Meagher, Mineral, Missoula, Powell, and Ravalli counties. Complex ores and base metals were also being sought.

NEVADA

The value of this state's nonfuel mineral output, an estimated $420,000,000, is 9 percent more than was reported in 1980. Nevada is the nation's leading producer of gold, mercury, and barite. Gold production increased to 417,200 ounces, a value of $194,500,000.

The main increase in production value resulted from the rise in gold production. Several new mines became operational during the year, including the Pinson, Alligator Ridge, and the Borealis. Anticipated annual yield from these operations should exceed 160,000 ounces. Freeport Gold Company began production from its Bell Mine; at full production it should be the largest gold source for the state. Numerous small gold heap leach or conventional milling operations were initiated during the year. Newmont Mining Corporation raised gold reserve estimates at its Gold Quarry property. This could produce 150,000 to 200,000 ounces annually. Late in the year, Newmont announced it would construct a new mill in the area. In November, Duval Corporation announced discovery of a gold-silver ore body near its Battle Mountain operations.

Silver King Mines, Incorporated dedicated its new $10,000,000 Taylor mine and mill in June; the first silver bullion was poured in May. Construction continued at Sunshine Mining Company's 16-to-1 silver mine and mill complex. Completion was scheduled for 1982.

Exxon announced the discovery of a substantial molybdenum deposit. However, full delineation may take several years. Weakening market conditons caused Day Mines Inc. to place its Victoria copper mine on inactive status and Union Carbide Corporation announced a similar situation at it Emerson tungsten mine.

NEW MEXICO

The value of nonfuel mineral production in New Mexico declined from $768,000,000 in 1980 to $727,000,000 in 1981, according to the U. S. Bureau of Mines. The leading commodities, potash and copper, provided more than 79 percent of the state's nonfuel mineral value. Copper production for the year is estimated at 169,708 tons valued at $288,000,000. Weakened markets and lower metal prices contributed to the slowdown in copper production.

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Corporation and Mitsubishi Corporation of Japan finalized their partnership to own, modernize, operate, and share production of Kennecott's Chino Mines Division copper mining and processing facilities near Silver City. Kennecott merged with Standard Oil of Ohio (SOHIO). Modernization of the Chino property, begun in 1980, will include a new 37,500-ton-per-day concentrator, a slurry pipeline from the concentrator to the smelter, and a modified smelter. One section of the concentrator was scheduled to go into production in June of 1982 and the other in August of 1982 with copper production expected to increase from 65,000 to 110,000 tons per year. Phelps Dodge Corporation announced plans for construction of a $31,000,000 copper solvent extraction-electrowinning plant scheduled to become operational at the end of 1982. The plant is expected to add approximately 16,500 tons of new copper production by further treating copper-bearing leach water percolated through the Tyrone mine's waste dumps. The new Quintana Minerals Corporation and Phibro Mineral Enterprises Incorporated's $78,000,000 open pit hillside copper mine was on schedule for production to begin in January 1982. Progress continued at the Molycorp Questa Division of Union Oil Company's $20,000,000 modernization and conversion of its open pit operation to an underground mine. Conveyor belts will transport the molybdenum ore to a crusher on the surface when production starts in mid-1983. Milling operations were halted in August so that mill modification could be started.

OREGON

Although not a major mining state, Oregon is of national importance as it is the sole domestic source of nickel. Estimated value of nonfuel mineral production was $145,000,000, of which nonmetals, including cement and other construction materials, accounted for 95 percent of the total.

Metals exploration and development activity continued at a relatively high pitch. In eastern Oregon, Veta Grande Corporation purchased a property in the Morman Basin where a dragline and washing plant reportedly recovered from 10 to 20 ounces of gold per day. Exploration continued at numerous mines including United Nuclear Mining & Milling Services' Cornucopia gold mine, W.A. Bowes and Associates' Cougar mine, Brooks Mineral and Amax at the North Pole and other mines.

In western Oregon, Hanna Mining Company continued production of nickel. Exploration efforts included: Amoco Minerals in the North Santiam area; Galactic Resources in the Bohemia district; Exxon U.S.A. in the Glendale area; American Selco at the Groff project. Inspiration Development, U. S. Nickel Company, and Hanna probed the nickel laterites.

New or expanded mineral processing activity and plans included Albany Titanium's plan to produce titanium sponge at a rate of 35,000 pounds per month. Oregon Metallurgical Corporation plans to install additional titanium ingot-melting furnaces. Union Carbode will close its ferroalloys plant at Portland and Reynolds Metals Company shut down two 25,000 ton per year potlines at its Troutdale aluminum plant. Reynolds is considering full closure of the Troutdale plant rather than attempt to meet new anti-pollution rules.

SOUTH DAKOTA

Nonfuel mineral production in South Dakota during 1981 was valued at $192,700,000, a decrease of 15 percent from the record high achieved during the previous year, according to preliminary figures. Declining prices received for gold, the state's leading commodity, produced during the year was the principal factor contributing to the lower level of total mineral output value. 274,000 ounces of gold were produced with a value of $127,700,000. Of this total, Homestake Mining Company's Lead mine was the premier producer.

South Dakota enacted legislation assigning a 6 percent severance tax on the gross yield from the sale of precious

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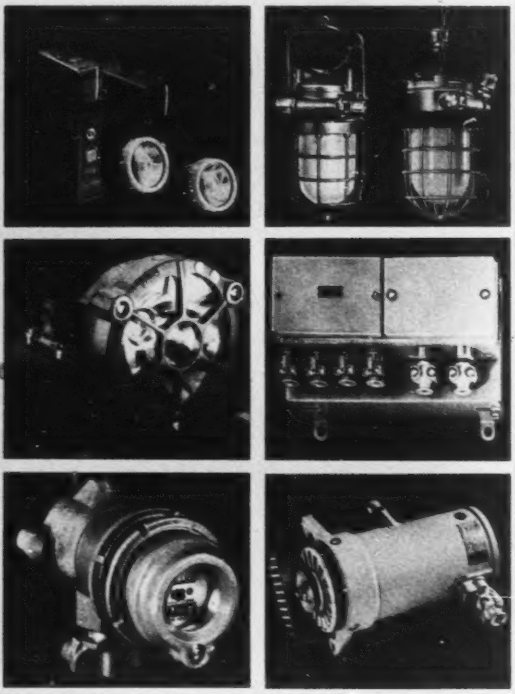

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metals in the state, effective July 1, 1981. The measure exempts producers of less than 1,000 ounces per year. The new tax replaces a net profits tax previously paid on precious metals production.

TENNESSEE

In 1981, the state was the nation's leading producer of zinc, ball clay, and pyrite. The value of nonfuel mineral production in Tennesee in 1982 was $445,400,000. Cement was the leading commodity in terms of value, followed by stone, sand and gravel, and gypsum, all recording production decreases from the year before.

Near year-end, Gulf & Western Industries Inc. announced the closing of the IdolMine in Granger County. At the same time, Jersey Miniere Zinc Company announced plans to double zinc concentrate output at its middle Tennessee operations by the end of 1982. Under the expansion program, the company will complete the cGordonsville mining and milling complex and operatore on a regular basis of 6,000 tons per day.

UTAH

Nonfuel mineral production in Utah for 1981 was $786,000,000 as compared to $772,000,000 in 1980. The total value of metals produced increased from $606,000,000 in 1980 to $617,000,000 in 1981. Settlement of the 1980 copper strike was the principal factor in a return to normal levels of copper output. Copper production, principally by the Utah Copper Division of Kennecott Minerals Company, a division of Kennecott Corporation, continued to account for half of the state's nonfuel mineral production and over 60 percent of its metal production. Lower prices of molybdenum, gold, and silver, byproducts of copper production, led to a decline in the dollar yield of those metals.

In May, Kennecott Corporation was taken over by Standard Oil Company of Ohio (SOHIO) and the company proceeded with plans to modernize the Bingham Canyon operations. The project proposed included the installation of ore crushing facilities at the open pit, a conveyor system to haul ore out of the pit, and construction of a new concentrator to replace the Bonneville, Magma, and Arthur mills. Underground development of the North Oreshoot continued and includes a 20-foot-diameter shaft sunk to 4,200 feet and about 10,000 feet of development drifting on several levels.

In the old West Mountain mining district, Anaconda Copper Company, a subsidiary of Atlantic Richfield Company, announced plans to suspend production for 1 year at its Carr Fork underground mine. The company has been unable to exceed 40 percent of production capacity and laid off 900 workers on the project. During the shut down period, the company planned extensive development work and resumption of production when market conditions improve.

Despite cutbacks in the copper industry, exploration and development projects for other metals were stepped up. Ranchers Exploration and Development Corporation began production of silver at its Escalante mine. The company anticipates the capacity of the new mill will be increased from 500 to 750 tons per day. Getty Minerals Resources Company entered a joint venture with Gold Standard, Incorporated to establish an open-pit mine and construct a 3,000 short-ton-per-day mill to process gold ores in the old Camp Floyd mining district. In the Tintic and East Tintic mining districts, Asarco Inc. is evaluating the Chief Consolidated Company property and the Sunshine Mining Company was reconditioning the Apex No. 2 shaft for reentry to property in the Burgin mine area. Bear Creek Mining Company and Anaconda Copper were also exploring in the area.

In the nonmetals group, leading commodities included portland cement, potash, salt, lime, sand and gravel, and native asphalt.

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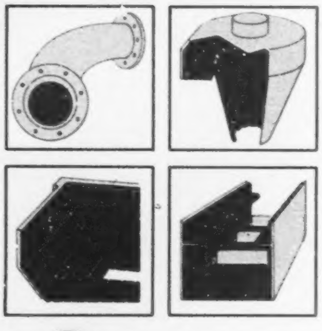

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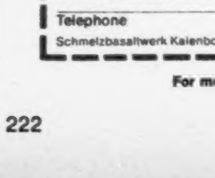

WASHINGTON

Estimated value of Washington's 1981 nonfuel mineral production was $219,000,000; nonmetal commodities accounted for 97 percent of this total. Major emphasis in nonmetals was on barite. C&E Minerals Company obtained properties and purchased the Calhoun mill. It planned to mine and process barite and other industrial minerals.

The state ranked first in the nation in production of primary aluminum, although the downturn in the economy resulted in cutback of production. The Aluminum Company of America reduced production at its Vancouver plant to 40 percent of capacity, and shut down one potline at its Wenatchee plant; Reynolds Metals Company shut down a 23,000 ton-per-year potline at its Longview plant.

Amax Inc. indicated its Mt. Tolman molybdenum project will be placed on hold due to adverse metal market conditions. Other mineral related activities include plans by International Titanium Inc. to construct a titianium sponge plant in the Moses Lake area.

WISCONSIN

Estimated value of the nonfuel mineral production of this state in 1981 was $166,500,000. Nonmetallic minerals used in construction continued to contribute the greatest value, followed by iron ore. Although value of mineral production remained low because of the depressed economy and cutbacks in construction, modest increases in value of cement and iron ore brought the state total over 1980 figures.

After several years of negotiation, the state's controversial mining tax law was amended. A new law that lowered net proceeds taxes on mining and strengthened environmental safeguards became effective. With the passage of the new law, Exxon Minerals Company, the owner of the Crandon zinc-copper deposit in Forest County, was conducting final engineering studies and examining the overall economics of the mining project. If economics prove favorable, the firm could apply for mining permits by mid-1982. Kennecott Minerals Company was also assessing the economics of mining the Flambeau copper-zinc deposit. At year-end the company was trying to resolve a local zoning issue that would allow mining to occur.

News of the discovery of a zinc-copper deposit, located on the Mole Lake Indian Reservation, was released. The deposit was discovered by the United States Geological Survey, who conducted exploration on the reservation in 1979-1980 under an interagency agreement with the United States Bureau of Indian Affairs. Details on tonnage and grade of the deposit have not been released.

WYOMING

Sodium carbonate and bentonite were the state's leading nonfuel mineral products for 1981; estimated value for the year was $867,000,000. Production of sodium carbonate decreased slightly from 1980, reflecting the nationwide slump.

Texasgulf Inc. received approval from the Wyoming Industrial Siting Commission in April to proceed with plans to double its 1,000,000-ton-per-year trona plant near Green River. However, owing to adverse market conditions, the $63,000,000 expansion was delayed indefinitely.

Chevron Chemical Company, a unit of Standard Oil Company of California, anounced plans to build a $300,000,000 phosphate fertilizer plant expected to yield 500,000 tons per year. The proposed plant would utilize phosphate rock from a Chevron Resources Company mine in Utah. NL Industries Inc.'s baroid division opened a 1,000-ton-per-day bentonite grinding, drying, and packing plant, doubling the firms bentonite production capacity in Wyoming. American Colloid Company also increased the capacity of its Lovell plant by adding another mill.

concentrate smelting process

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Polaris—the world's most northerly mine 46

SEPTEMBER 1982
VOLUME 35, NO. 9

World Mining

THE COVER

Aerial view of Cominco Ltd.'s Polaris Mine. Polaris began production in early 1982 and is the world's most northerly mine, located at 77° latitude on Little Cornwallis Island, Northwest Territories, Canada. To develop and operate in such an isolated and harsh environment demanded an innovative approach. This included the construction of Polaris' mill in southern Canada on a barge which was then towed 3,000 miles (4,800 kilometers) to the mine. *Photograph by Cominco Ltd.*

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Where are the large producers and how did mine production compare with former years?

United States open pit and underground mine tonnages

By **George O. Argall, Jr.**
Senior Editor
(text)
Patrice Rapalus
Assistant Production Editor
(compilation)

Underground and open pit mine production during the first quarter of 1981 started at a high rate. Copper mines which recovered from the long strike in 1980 operated at normal rates. Iron ore mines production was near capacity and Florida phosphate production was at high levels. But by year-end, lower prices and declining markets for metals and minerals resulted in cut backs in production as well as closure of many mines. Possibly the only exceptions to the long list of metals affected by mine closures were gold and silver. However, by year-end lower prices for these metals were of concern to mine operators. No mass closures took place as was the case in the copper industry.

It was a sad year for many old mines that were permanently closed. Even some of the mines closed in the later part of the year may never reopen. The most notable closure was that of the Bunker Hill Company shortly after the August announcement that the company would be liquidated and the mill, smelter, and related facilities sold. No buyer was located during the year. Nevertheless, the Bunker Hill mine raised output over 1980 by 66,300 tons to 601,351.

In Colorado, the Eagle mine of New Jersey Zinc Company was closed after 98 years of continuous operation. The mine produced high grade copper-silver-gold ore during the 1929-1931 depression to keep operating and since then has been Colorado's largest zinc producer.

Another zinc mine closure was the Edwards mine in New York, owned by St. Joe Minerals Corporation. More than 1,300,000 tons of zinc concentrates had been recovered from its ores since 1926.

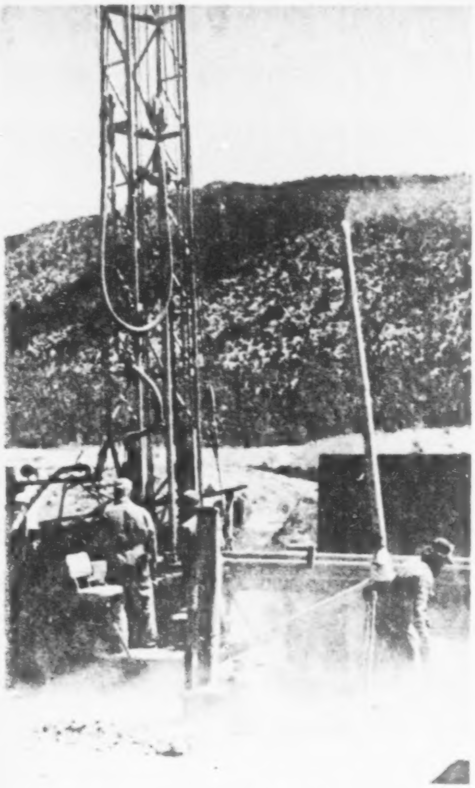
Asarco, Inc. pulled the pumps at its

Short tons of ore mined from United States underground mines

Company	Mine	1974	1975	1976	1977	1978	1979	1980	1981
Amax Chemical Corp.	Carlsbad Potash	2,642,500	2,850,129	3,000,000	3,437,000	3,454,391	3,563,732	3,621,546	4,130,347
Amax Lead Company of Missouri[1]	Buick	1,556,420	1,634,000	1,614,000	1,612,082	1,440,216	1,880,857	1,653,752	881,127
Amax Inc.	Climax	12,191,464	11,835,470	12,069,670	11,009,670	16,484,000	9,836,795	10,187,406	10,792,887
	Urad	1,478,866	—	—	—	—	—	—	—
	Henderson	—	—	659,014	4,543,000	6,933,400	9,382,415	10,327,374	9,257,000
Asarco Inc.	Galena	176,696	178,382	182,272	177,704	176,782	181,000	192,000	197,000
	Coeur	—	—	41,978	146,924	151,989	156,000	165,000	164,000
	Ground Hog	125,370	122,703	130,508	135,996	46,743	—	—	—
	Leadville	158,920	200,170	199,820	186,000	189,000	173,900	202,000	209,000
	Tennesee Mines Total	2,157,735	1,884,955	1,832,885	2,019,857				
	includes Immel	—	513,325	527,952	581,441				
	Young	—	690,240	737,622	787,553	1,638,166	1,624,530	2,698,000	2,893,000
	Coy	—	—	11,954	1,531				
	New Market	—	608,169	553,612	645,380				
	Troy	—	—	—	—	—	—	—	577,000[12]
Atlas Minerals	Green River District	N.A.	N.A.	N.A.	N.A.	N.A.	65,778	80,909	N.A.
	Pandora	N.A.	N.A.	N.A.	N.A.	N.A.	79,694	44,750	N.A.
	Patti Ann Elephant	N.A.	N.A.	N.A.	N.A.	N.A.	86,853	23,758	N.A.
	Rim-Callahan-Sage	N.A.	N.A.	N.A.	N.A.	N.A.	60,200	53,054	N.A.
	School Section Standard	N.A.	N.A.	N.A.	N.A.	N.A.	69,595	4,933	N.A.
	Velvet	N.A.	N.A.	N.A.	N.A.	N.A.	3,598	89,164	N.A.
	Wood	N.A.	N.A.	N.A.	N.A.	N.A.	8,598	—	N.A.
Bethlehem Mines Corp.	Grace Mine	2,568,880	2,118,727	2,091,535	1,112,575[10]	—	—	—	—
Bunker Hill Company	Bunker Hill	691,849	711,130	818,807	456,000	545,572	530,796	535,051	601,351[16]
	Crescent	26,163	30,987	26,465	15,000	31,343	34,932	35,078	25,360
	Pend Oreille	231,268	306,184	360,581	154,000	—	—	—	—
Cities Service Co.	Calloway	340,308	400,001	378,900	273,541	449,000	440,000	435,000	N.A.
	Boyd	177,177	349,757	388,400	196,711	280,000	234,000	192,000	N.A.
	Cherokee/School Property	582,701	855,202	1,159,800	643,105	959,000	1,049,000	1,012,000	N.A.
Clayton Silver Mines Company	Clayton	63,644	79,807	91,061	N.A.	N.A.	N.A.	51,932	58,258
Cleveland Cliffs Iron Co.	Mather	1,839,412	1,957,000	1,671,000	1,114,000	1,804,000	1,082,000	N.A.	N.A.
C.F. & I. Steel Corp.	Sunrise	487,337	476,378	385,421	372,603	439,495	432,680	245,636	—[11]
Cominco American, Inc.	Brock/Warm Springs	270,000	N.A.	191,000	162,000	184,000	192,000	202,000	201,600
	Magmont (50% Cominco)	1,140,000	1,000,000	1,070,000	1,094,000	1,050,000	1,096,000	1,084,000	1,127,000
	Montana Phosphate	—	270,000	270,000	—	—	—	—	—
Cyprus Mines Corp.	Bruce Mine Division	92,820	94,608	90,278	40,710[3]	—	—	—	—
Diamond Crystal Salt	Jefferson Island	1,538,040	N.A.	1,400,000	1,233,000	1,466,997	1,480,135[7]	1,311,709	—[14]
	Akron[5]	—	—	—	241,149	235,693	235,000	N.A.	N.A.
	St. Clair[6]	—	—	—	305,350	322,706	368,000	N.A.	N.A.
Duval Corp.	Nash Draw	2,106,669	2,285,603	2,155,841	1,115,222	846,509	882,000	955,800	1,013,000
	North	—	—	21,461	640,029	1,077,021	405,000	—	—
Eagle-Picher Industries, Inc.[22]	Shullsburg	284,713	260,123	288,000	308,000	164,300	—	—	—
	Bearhole[1]	141,268	132,802	158,000	205,000	37,000	—	—	—

Company	Mine	1974	1975	1976	1977	1978	1979	1980	1981
Exxon Minerals Company	Highland	—	—	—	70,000	138,843	131,300	135,700	N.A.
FMC Corp.	Green River-Trona	3,165,000	3,600,000	4,194,000	4,703,000	4,584,000	4,820,000	4,822,000	5,005,000
Federal Resources Corp.	Camp Bird	85,840	104,398	82,970	27,158	14,634	—	26,386	—
	Bonny & 85 Mine	57,996	3,868	—	—	—	—	—	—
	Mada Waska	—	—	82,319	295,068	N.A.	390,366	397,065	N.A.
Hecla Mining Co.	Dayrock	67,559	24,134	—	—	—	—	—	—
	Grayrock	20,674	22,118	19,533	21,027	3,328	—	—	—
	Lucky Friday	165,695	173,245	186,520	182,412	158,600	175,908	189,348	148,864
	Star Unit	281,580	282,161	282,037	293,466	290,200	284,113	281,856	131,679
	Sunshine Unit	—	62,034	13,447[5]	44,024[15]	—	153,714	42,968	51,645[15]
Hecla-Day Mines, Inc.	Sherman	—	—	28,00	53,514	85,066	98,598	97,601	—
	Tamarack	—	—	—	—	1,295	14,588	—	—
	Republic	—	—	—	—	—	23,815	43,947	62,718
	Victoria	—	—	—	—	—	—	—	124,575
Homestake Mining Co.	Homestake	1,559,770	1,473,382	1,650,442	1,589,286	1,586,549	1,429,886	1,786,521	1,848,803
	United Nuclear-Homestake	227,009	325,950	461,140	334,113	546,147	766,293	2,107,504	344,081
	Bulldog Mountain	87,973	104,470	117,783	113,672	110,385	97,438	100,579	103,609
	F-33	33,596	23,929	—	—	—	—	—	—
Idarado Mining Co.	Idarado	387,697	374,524	361,250	300,750	198,650	—	—	—
Inland Steel Co.	Sherwood	379,323	277,848	220,000[1]	206,790	215,586	—	—	—
Inspiration Consolidated Copper Co.	Black Pine	—	54,000	68,000	64,000	77,000	74,000	N.A.	N.A
International Minerals & Chemical Corp.	Carlsbad	900,000	4,644,000	4,037,000	5,000,000	4,960,582	5,090,000	5,600,000	5,500,000
Kennecott Copper Corp.	Tintic	161,544	175,000	331,775	—	—	—	—	—
Kerramerican, Inc.	Blue Hill	206,400	211,211	176,079	143,200[21]	—	—	—	—
Kerr McGee Corp.	New Mexico Potash	2,850,000	2,150,000	2,150,000	N.A.	3,108,456	3,071,768	N.A.	N.A.
	Ambrosia Lake	874,434	960,531	900,000	1,000,000	1,165,618	1,173,828	1,595,450	1,562,860
Magma Copper Company	San Manuel	19,725,713	16,778,247	15,011,111	17,000,000	19,638,032	21,828,905	13,803,276[20]	22,198,000
	Superior	732,937	955,943	971,313	1,034,563	980,837	973,295	556,846[20]	1,022,222
Meramec Mining Co.	Pea Ridge	2,267,031	2,651,793	2,600,956	2,062,543	—[6]	755,000	1,236,000	1,695,184
Minerva Oil Co.	Crystal-Victory	9,882	6,186	—	—	—	—	—	—
	No. 1	153,297	135,785[4]	—	—	—	—	—	—
	Gaskins	50,528	47,859[4]	—	—	—	—	—	—
	Deardorff	36,727	11,198[4]	—	—	—	—	—	—
	Spivey[22] (now of Allied Chem.)	145	8,394	30,000	N.A.	N.A.	N.A.	N.A.	N.A.
National Potash Co.	Eddy	1,731,000	1,684,418	1,000,000	—	—	—	—	—
	Lea	—	73,922	770,000	1,669,648	1,789,111	1,903,364	1,765,000	
New Jersey Zinc. Co.	Eagle	200,232	176,648	179,640	167,627	—	—	—	—
	Jefferson City	363,535	380,628	431,436	442,834	430,000[1]	453,879	480,498	N.A.
	Austinville	596,000	640,000	546,516	533,359	460,563	490,635	531,738	N.A.
	Friedensville	420,000	450,000	479,477	519,589	494,647	526,603	527,041	541,033
	Sterling	196,499	180,587	207,329	207,798	191,988	200,000	200,928	113,000
	Elmwood	—	180,500	405,413	639,581	600,000[1]	684,291	N.A.	N.A.
Noranda	Lakeshore	—	—	—	1,279,283	1,216,000	—	—	—
Ozark Lead Co.	Sweetwater	1,458,756	1,339,300	1,309,266	1,400,000	1,435,326	1,040,155	1,625,353	1,880,000
Pathfinder Mines Corp.	Lucky Mc	—	—	11,000	7,600	19,680	18,027	13,924	10,067
Phelps Dodge Corp.	Copper Queen Bisbee	480,375	108,167[4]	—	—	—	—	—	—
Pilot Knob Pellet Co.	Pilot Knob Pellet	1,685,500	1,806,005	1,921,075	1,795,308	1,741,347	1,753,826	—	N.A.[13]
Ranchers Exploration & Development	Johnny M.	—	—	35,400	108,220	176,850	157,422	164,603	N.A.
	Hope Mine	—	—	60,000	38,883	65,152	48,840	29,572	N.A.
Reynolds Mining Corp.	Saline County	99,000	76,000	60,000[1]	—	—	—	—	—
Rio Algom Corporation	Lisbon	231,208	254,523	267,020	273,527	262,005	274,476	270,093	238,026
Sohio Natural Resources Co.	J. J. No. 1	—	—	—	164,200	262,000	156,000	243,000	N.A.
St. Joe Minerals Corp.	Balmat	1,232,462	1,246,733	1,239,456	1,194,510	433,163	159,000[6]	67,142	561,957
	Brushy Creek Division	1,202,656	1,139,632	4,813,182	1,229,202	1,262,006	1,234,679	1,208,353	3,812,067
	Indian Creek Division	689,608	606,550		651,802	481,178	639,431	637,598	
	Viburnum Division	2,011,247	1,716,357		1,215,122	1,271,484	1,999,576	1,124,513	
	Fletcher Division	1,301,016	1,085,252		1,821,881	1,987,778	1,240,676	1,228,049	
Standard Metals Corp.	Sunnyside	205,000	210,000	224,644	265,217	122,702	—	119,705	20,000
Standard Slag	White Eagle	—	—	—	573	1,183	1,183	—	—
Stauffer Chemical Co. of Wyoming	Big Island	2,807,000	2,400,000	2,618,000	2,620,000	3,000,000	3,000,000	2,783,036	N.A.
Sunshine Mining Co.	Sunshine	162,046	225,897	45,689	155,116	200,850	172,228	50,961[14]	197,154
Texasgulf, Inc.	Granger	—	—	140,000	800,000	1,600,000	937,606	877,000	1,684,000
Union Carbide Corp.	Uravan Mineral Belt	274,134	312,000	341,000	415,000	407,000	440,000	N.A.	N.A.
Union Carbide Nuclear Co.	Pine Creek	710,396	690,000[1]	715,000[1]	731,000[1]	750,000[1]	515,000	465,000	N.A.
UV INdustries, Inc.	Continental	700,000	495,000	668,433	663,283	158,745[7]	546,097	711,754	519,260
Western Nuclear, Inc.	Congo	—	—	—	19,877	15,687	20,125	N.A.	N.A.
	Paydirt Incline	—	—	—	1,280	237	—	N.A.	N.A.
	Sheep I	—	—	—	14,456	56,416	55,571	N.A.	N.A.
	Golden Goose II	—	—	—	29,689	17,603	2,252	N.A.	N.A.
White Pine Copper Co.	White Pine	8,266,823	9,003,750	3,890,000	3,221,890	3,135,138	3,660,000	3,513,000	4,153,000

N.A. Not available. 1. Estimated. 2. Second shaft closed from March through December due to cave-in. 3. Permanently shut down, July 4, 1977. 4. Closed down June 13, 1975. 5. Strike from March 11, 1976. 6. Strike from June 11, 1978 to July 16, 1979. 7. Nine-month strike. 8. Solution mines. 9. Closed 1977. 10. Permanently shut down July, 1977. 11. Closed 1978. 12. Closed October 1977. 13. Closed June 1980. 14. Closed November 1980 due to flooding. 15. Figure indicates Hecla's share only. 16. 238 day strike in 1980. 17. Jointly owned with Homestake. 18. Closed July 3, 1980. 19. Closed September 1980. 20. 1980 production reduced by fire and strike. 21. Operating at partial capacity. 22. Sold to Inspiration Copper in 1981. 23. On strike March 15 to November 17.



ALLIGATOR RIDGE was one of many new Nevada gold mines going on stream in 1981.

Ground Hog zinc-lead-silver mine in New Mexico. Last regular ore production was in 1978. Gulf and Western Industries, Inc. closed its idle zinc mine in Tennessee near year-end. Another mine closure by Gulf and Western's New Jersey Zinc Company was the Austinville zinc mine in Virginia. This was the oldest metal mine in the United States and had operated, almost consistently, since 1756.

All of the above mines were closed permanently, according to the owners. This article is not the place to list temporary 90-day closures and extended vacations of many other mines which took place in 1981.

New Mine Openings

There was also good news of new mine openings during the year. A major new underground mine which reached production was the Troy copper-silver mine of Asarco Inc., located in Montana, where 577,000 tons of ore were mined.

Three new underground mines were under development and will reach production during 1982. Only development ore was mined in 1981 and is not considered as production. These mines are the Viburnum No. 35 mine of St. Joe Minerals Company in the "New Lead Belt" of Missouri; the Springer tungsten mine of Utah International Inc. in Nevada, and the Escalante silver mine of Rancher's Exploration and Development Corporation in Utah.

The San Manuel copper mine of Magma Copper Company in Arizona has the capacity and traditionally has been the largest underground mine in the United States. Only in those years when long copper strikes have closed the mine has the Climax mine of Amax, Inc. in Colorado been the largest undergound mine, if operating at capacity. In 1981, San Manuel set a record high output of 22,198,000 tons of ore mined. In the strike year of 1980 its total output fell to 13,803,276 tons.

Amax, Inc. mined 10,792,887 tons of ore at its Climax mine in Colorado; 1980 production was 10,187,406 tons. At the company's nearby, but separate, Henderson mine tonnage was 9,267,000, a small decline from the 10,327,374 tons mined in 1980.

A notable feature of underground mining was the resumption of production (1,767,000 tons) at the Lakeshore copper mine in Arizona by its new owner—Noranda Mines Ltd. of Canada. There was no production in 1980 and the highest previous mining tonnage was 1,279,283 tons in 1976.

White Pine Copper Company raised production to over 4,000,000 tons for the first time in six years. The 4,153,000 tons mined was far below the all time high of 9,003,750 tons mined in 1975.

Fourth largest producer was the Carlsbad potash mine of International Minerals and Chemical Company in New Mexico at 5,500,000 tons.

For the first time trona output from a single mine in Wyoming was over 5,000,000 tons in a year. FMC Corporation's Green River mine production was 5,006,000 tons. This mine was the fifth largest in the United States after San Manuel, Climax, Henderson, and International's Carlsbad.

Another mine producing more than 4,000,000 tons was Amax Chemical Company's Carlsbad potash mine in New Mexico (4,130,347).

A comparison of the yearly tonnages mined in the adjoining table shows that several lead and zinc mines raised output.

Open pits out, new gold mines

In Arkansas, Reynolds Mining Company closed its open pit bauxite mines. For many years they were the largest bauxite mines in the United States. At the year-end, Kaiser Steel Corporation closed its Eagle Mountain iron ore mine and pellet plant in California. The company shut down its blast furnaces at Fontana so there was no market for the ore.

Short tons of ore mined and waste stripped at key United States open pit mines

		1978		1979		1980		1981	
Company	Mine	Ore Mined	Waste Stripped	Ore Mined	Waste Stripped	Ore Mined	Waste Stripped	Ore Mined	Waste Stripped
Agrico Chemical Co.	Payne Creek	8,287,000[1]	20,339,000	11,000,000	23,000,000	11,000,000	25,000,000	N.A.	N.A.
	Ft. Green	11,674,000[1]	26,955,000	16,000,000	28,000,000	17,000,000	26,000,000	N.A.	N.A.
	Saddle Creek	1,375,000	4,720,000	1,300,000	2,800,000	2,000,000	6,000,000	N.A.	
Amselco Nat. Resources	Alligator Ridge	—	—	—	—	—	—	409,000	1,922,700
Asarco, Inc.	Mission	7,778,000	32,952,700[13]	4,816,900	3,670,000	1,117,500	3,910,500	4,779,000	3,689,000
	Silver Bell	3,568,500	5,162,000	3,712,900	5,438,700	2,207,400	3,407,200	3,689,000	N.A.
	Sacaton	4,153,000	11,068,900	4,005,600	12,361,600	3,818,700	11,784,800	4,103,000	N.A.
	San Xavier	1,991,000	2,325,400	870,000	1,391,500	502,000	3,957,200	1,740,000	N.A.
Anaconda Minerals Co.	Berkeley	17,890,000	47,102,000	17,115,000	50,681,000	9,000,000	25,000,000	15,000,000	40,000,000
	Jackpile-Paquate	2,372,000	29,458,500	—	—	—	—	—	—
	Tonopah (Hall)	—	—	—	—	—	—	1,186,000	44,,397,000
Anamax Mining Co.	Twin Buttes	10,897,110	21,665,222	11,275,101	40,168,439	9,692,228	32,163,131	10,941,000	39,619,000
Bear Creek Uranium Corp.	Bear Creek	338,000	9,538,400[1]	420,000	19,500,000	540,000	15,800,000	N.A.	N.A.
Benton Clay Co.	Lone Bear Midwest T&W Midwest North	16,947	—	25,475	29,547	—	—	—	—
	Kaycee Durand	516	—	811	—	—	—	—	—
	Kaycee Brock	35,094	—	70,080	83,563	51,362	194,230	N.A.	N.A.
	Kaycee Hanson	—	—	28,422	272,303	55,132	373,676	N.A.	N.A.

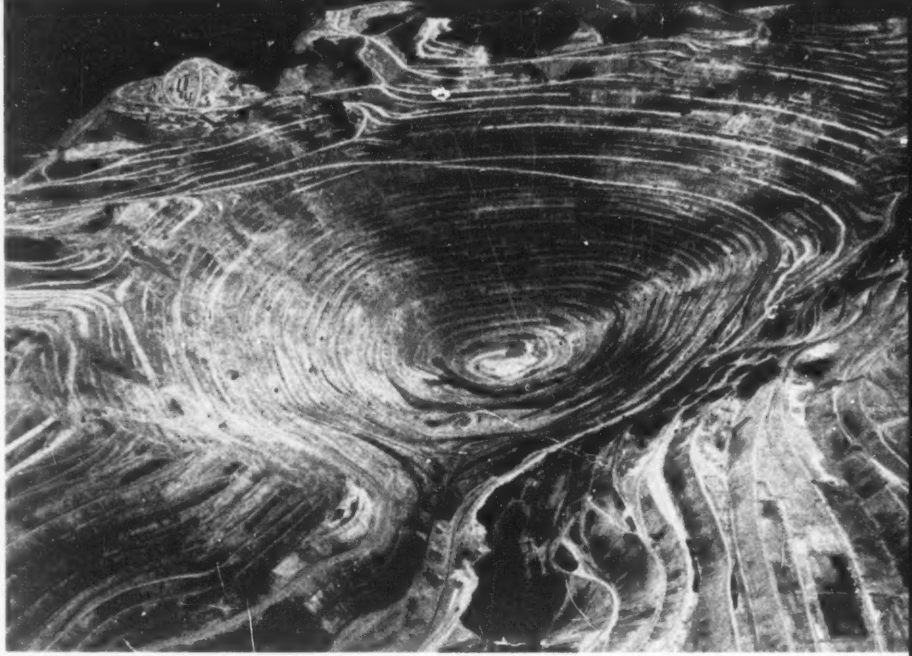
Company	Mine	1978		1979		1980		1981	
		Ore Mined	Waste Stripped	Ore Mined	Waste Stripped	Ore Mined	Waste Stripped	Ore Mined	Waste Stripped
Brewster Phosphates	Haynsworth	11,092,055	21,545,438	10,789,508	18,525,589	10,145,136	21,350,943	10,579,929	20,311,555
	Lonesome	10,258,621	17,923,280	10,630,875	22,329,548	10,374,924	24,029,934	10,765,209	21,385,861
Candalena Partners	Candaleria	—	—	—	—	1,197,412	2,012,513	1,691,011	N.A.
Carlin Gold Mining Co.	Carlin	660,600	7,588,000	769,800	7,993,200	709,000	7,226,000		
	Bootstrap	95,400	411,300	—	—	—	—	787,000	9,613,000
	Blue Star	279,300	1,824,800	226,300	835,200	229,000	326,000		
	Maggie Creek	—	—	—	—	251,000	1,916,000		
Chevron Resources Co.	Panna Maria	30,000	4,700,000[1]	770,000	12,000,000	970,000	18,000,000	N.A.	N.A.
Cities Service Co. Miami Copper Ops.	Pinto Valley	15,809,000	25,380,000	17,232,500	30,280,130	11,064,473	17,967,270	18,500,000	N.A.
Cleveland-Cliffs Iron Company	Tilden	11,994,000	12,159,000	15,883,000	16,100,000	21,775,000[2]	N.A.	N.A.	N.A.
	Canisteo	3,106,000	2,605,000	3,100,000	2,600,000	1,300,000[2]	N.A.	—	—
	Republic-Humboldt	5,219,000	9,764,000	5,300,000	9,800,000	720,767	N.A.	N.A.	N.A.
	Empire	17,748,000	27,912,000	17,718,000	28,000,000	15,500,000[2]	N.A.	N.A.	N.A.
Climax Molybdenum Co.	Climax	6,328,669	14,923,675	6,838,156	13,532,282	6,884,664	17,922,070	5,993,336	21,640,878
Continental Oil Co.	Conquista	1,047,000	32,100,000	1,188,000	32,200,000	N.A.	N.A.	—	—
Cortez Mines Corp.	Cortez Gold	—	—	—	—	634,100	—	1,349,000	N.A.
Cyprus Mines Corp.	Cyprus Bagdad	13,536,000	23,454,000	14,593,136	26,179,782	14,943,000	22,682,000	14,794,000	26,460,000
	Cyprus Johnson	1,563,030	2,566,598	1,202,500	3,045,700	1,588,545	2,029,882	1,499,600	2,607,200
	Cyprus Pima	—	—	2,524,417[1]	13,218,297	7,307,944	45,882,310	11,416,490	34,882,317
Cyprus Mining Co.	Thompson Creek	—	—	—	—	—	—	—	12,000,000
Dawn Mining Co.	Midnight	542,528	4,101,341	642,806	3,960,950	180,000	4,560,000	171,700	N.A.
Duval Corp.	Battle Mountain	779,800	5,643,200	955,200	6,604,500	1,085,600	8,078,860	1,233,600	11,083,300
	Esperanza	—	—	4,900,400	6,301,700	6,187,500	4,613,100	6,176,500	12,234,900
	Mineral Park	6,516,000	9,546,100	6,321,605	10,782,205	6,258,100	10,881,601	6,230,500	9,023,600
	Sierrita	33,555,900	44,715,400	33,413,201	30,593,500	33,856,000	39,256,300	32,614,300	35,742,400
Earth Resources Co.	Delamar	608,000	2,845,000	805,000	3,777,000	750,000	5,440,000	N.A.	N.A.
Eisenhower Mining Co.	Eisenhower	—	7,273,000	8,959,800	27,311,000	7,276,800	18,858,800	2,994,000	N.A.
Estech General Chemicals Co.	Watson	3,662,000	6,851,000	3,973,000	7,802,000	N.A.	N.A.	N.A.	N.A.
	Silver City	4,770,000	3,567,000	4,010,000	3,160,000	N.A.	N.A.	N.A.	N.A.
Eveleth Taconite Co.	Thunderbird	15,456,565	12,243,646	18,476,052	13,053,080	17,748,497	15,805,641	18,409,634	12,500,000
Exxon Company, U.S.A.	Highland Uranium	1,578,000	27,513,843	1,153,700	46,081,000	921,500	41,463	N.A.	N.A.
Federal Bentonite Co.	Upton	103,900	2,000,000[1]	142,000	1,300,000[1]	198,000	1,800,000	N.A.	N.A.
	Colony	292,000	4,200,000[1]	587,000	3,400,000	100,000	9,000	N.A.	N.A.
Foote Mineral Co.	Kings Mountain	327,788	2,034,935	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Freeport Gold Co.	Jerritt Canyon	—	—	—	—	—	—	577,000	N.A.
Gardinier, Inc.	Ft. Meade	5,480,000[1]	7,660,000[1]	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Gold Fields Mining Co.	Ortiz	—	—	—	—	—	—	980,000	300,000[2]
W.R. Grace Co.	Bonny Lake	3,900,000[1]	13,700,000[1]	4,506,700[1]	13,425,700[1]	5,051,600[1]	13,021,400[1]	2,800,000	N.A.
	Hooker's Prairie	5,700,000[1]	6,100,000[1]	6,576,200[1]	8,810,900[1]	7,665,700[1]	10,109,700[1]	1,500,000	N.A.
Hanna Mining Co.	Groveland	4,963,462	8,839,044	5,252,945	9,356,342	N.A.	N.A.	N.A.	N.A.
	Hanna Nickel	1,717,426	1,471,380	2,194,847	1,627,740	N.A.	N.A.	N.A.	N.A.
	Butler Taconite	8,587,359	4,619,910	7,563,912	2,138,388	4,900,000	1,697,032	N.A.	N.A.
	National Pellet	17,588,069	9,386,901	19,284,494	9,453,327	7,300,516	481,000	8,425,000	1,200,000
Houston International	Borealis	—	—	—	—	—	—	104,000	303,000
Humphreys Mining Co.	Folkston[15]	3,544,000	—	3,284,000	—	—	—	—	—
Inland Steel Co.	Minorca	5,986,708	3,909,990	4,500,000[2]	1,500,000[2]	5,161,776	2,061,086[1]	8,067,487	4,600,000
Inspiration Consolidated Copper Co.	Christmas	—	—	920,000	2,461,000	1,292,000	4,011,000	900,000[2]	3,500,000[2]
	Live Oak	718,000	338,000	246,000	128,000				
	Ox Hide		—	—	—	—			
	Red Hill	596,000	181,000	30,000	3,546,000	10,127,000	12,062,000	6,100,000[2]	30,000,000[2]
	Thornton	3,773,000	9,200,000	3,567,000	6,586,000				
	Joe Bush	543,000	6,023,000	2,262,00	9,550,000	4,347,500	21,500,000		
	Inspiration (all)	5,630,211	15,741,947	6,105,000	19,810,000				
International Minerals & Chemical Corp.	Clear Springs	9,851,000	9,374,000	11,261,000	7,910,000	9,820,000	8,413,000[11]	10,505,000	4,665,000[1]
	Noralyn	15,096,000	20,806,000	17,871,000	17,579,000	16,199,000[1]	12,211,000[1]	15,628,000[1]	9,730,000[1]
	Kingsford	17,422,000	27,022,000	16,880,000	28,803,000	13,087,000	19,656,000	13,190,000	21,048,000[1]
	Ag Operations	45,560,000[2]	65,810,000[2]	—	—	—	—	—	—
Jackson County Iron Co.	Black River Falls	2,066,739	6,474,270	2,096,196	6,965,395	1,990,807	5,415,973	—	—
Jones & Laughlin Steel Co.	Hill Annex (Main Pit)	2,963,067	35,887	196,925	—	—	—	—	—
	McKinley Mine	1,486,744	1,947,914	558,601	272,512	982,089	845,368	—	—
Kaiser Steel Corp.	Eagle Mountain	8,884,583	36,039,500	9,033,152	35,296,400	6,751,296	25,609,900	7,213,795	26,252,400
Kaycee Bentonite Co.	Kaycee Bentonite	N.A.	N.A.	N.A.	N.A.	201,000	650,000	N.A.	N.A.
	Ten Sleep	N.A.	N.A.	N.A.	N.A.	221,000	1,050,000	N.A.	N.A.
Kennecott Copper Corp. Chino Mines Div.	Chino	6,200,513	21,500,000[2]	7,162,501	24,800,000[2]	5,432,000	20,500,100[2]	6,386,070	42,132,871
Nevada Mines Div.	Liberty, Ruth, Tripp-Veteran	1,674,746	8,500,000[2]	—	—	—	—	—	—
Ray Mines Div.	Ray	11,621,230	27,500,000[2]	14,202,000	30,000,000[2]	10,963,460	33,010,210[2]	14,816,000	27,878,960
Utah Copper Div.	Bingham	35,937,700	115,004,191	37,804,000	123,181,836	31,578,000	107,000,000	39,024,000	134,274,849

In addition, the stripping ratio had increased rapidly during the last several years so furnace feed grew ever more expensive. In 1981, 26,252,400 tons of waste and 7,213,795 tons of ore were mined. Thus, the stripping ratio was 3.64 to 1.0. This ratio was 3.79 to 1.0 in 1980, 3.91 to 1.0 in 1979, and a high of 4.08 to 1.0 in 1977. This waste was rock requiring drilling and blasting; therefore mining costs were higher than for the softer natural ore pits on the Mesabi Range.

There were several tens of new small open pit gold mines in Montana and Nevada supplying ore to heap leaching pads. Daily tonnage was small. However, there were two new major gold pits in Nevada. Houston International Com-

Company	Mine	1978 Ore Mined	1978 Waste Stripped	1979 Ore Mined	1979 Waste Stripped	1980 Ore Mined	1980 Waste Stripped	1981 Ore Mined	1981 Waste Stripped
Kerr-McGee Corp.	Wyoming Uranium	—	1,346,958[1]	276,345	3,707,463[1]	183,991	979,321	104,492	N.A.
Little Hill Mines	Gold Hill	37,049	N.A.	49,144	N.A.	36,389	N.A.	N.A.	N.A.
Lone Star Steel Co.	Lone Star	N.A.	N.A.	N.A.	N.A.	1,150,155	2,065,699	N.A.	N.A.
McDermitt Joint Venture	McDermitt	246,700	1,377,500	N.A.	N.A.	394,940	910,351	N.A.	N.A.
Mobil Chemical Co.	Fort Meade	10,700,000	9,700,000	12,700,000	12,000,000	14,300,000	16,100,000	4,500,000	19,000,000
	Nichols	5,800,000	6,100,000	6,400,000	11,200,000	6,100,000	11,500,000		
Molycorp, Inc.	Mountain Pass	292,760	201,830	298,760	201,830	387,000	219,000	N.A.	N.A.
	Questa	4,400,000	2,300,000	N.A.	N.A.	611,000	1,658,000	N.A.	N.A.
Monsanto Co.	Tennessee Mines	1,900,000	5,700,000[1]	2,200,000	6,600,000[1]	900,000	3,000,000	N.A.	N.A.
	Henry	750,000	3,000,000[1]	750,000	3,000,000[1]	700,000	2,800,000[2]	N.A.	N.A.
N.L. Industries Inc.[3]	McIntyre Dev.	364,562	622,575	—	—	667,000	256,000	N.A.	N.A.
	Rossi Mine	232,000	650,000[2]	—	—	750,000[2]	N.A.	N.A.	N.A.
Nevada-Barth Corp.	Barth	191,431	117,888	187,000	N.A.	33,780	N.A.	N.A.	N.A.
Pathfinder Mines Corp.	Lucky Mc.	1,077,000	20,815,000[1]	357,586	5,471,247	291,564	8,660,608	200,124	2,267,623
	Shirley Basin	878,000	24,469,000[1]	670,270	28,000,000[2]	632,000	26,750,000	N.A.	N.A.
	Big Eagle	284,000	11,009,000[1]	159,831	2,700,000[2]	395,000	6,633,000	N.A.	N.A.
Pegasus Gold Ltd.	Zortman Mine	—	—	—	—	218,000	200,000	675,000	620,000
Landusky Mine	—	—	—	—	—	500,000	500,000	615,000	724,000
Petrotomics	Felder Operations	188,000	3,070,000	N.A.	N.A.	N.A.	N.A.	399,501	27,989,000
	Section 4	762,000	40,131,000	4,000	61,000,000	351,555	54,473,000		
Phelps Dodge Corp.	Morenci	17,938,587	25,809,101	21,712,798	29,132,171	17,692,768	29,558,944	28,740,707	46,966,583
	Ajo (New Cornelia)	8,486,019	11,486,355	10,188,883	10,435,815	7,042,202	8,956,647	9,609,354	13,480,391
	Tyrone	14,981,372	53,625,671	17,770,783	62,347,498	16,499,008	68,324,802	14,821,362	56,691,070
	Metcalf Pit	11,321,803	17,357,528	9,226,043	21,259,790	2,416,765	7,612,107	—[14]	—[14]
Pickands Mather Co.	Erie Mining	21,679,748	19,919,676	26,035,016	24,207,341	16,778,798	21,209,050	23,772,622	21,569,342
	Hibbing Taconite	20,997,528	12,646,129	23,592,004	14,295,777	27,992,000	8,000,000	25,035,147	12,607,156
Pinson Mining Co.	Pinson Pit	—		—	—	121,742	1,877,244	4,414,048	N.A.
Quintara Mining Co.	Hillside	—	—	—	—	—	—	—	5,300,000
Ranchers Exploration & Development Corp.	Bluebird	1,033,799	2,908,827	3,779,043	2,942,561	3,993,123	4,479,711	231,926	N.A.
Reserve Mining Co.	Peter Mitchell	27,173,000	6,176,432[1]	20,756,119	5,651,627[1]	14,948,151	1,637,138	25,991,000	5,765,897[1]
Reynolds Mining Corp.	Bauxite	671,000	6,500,000	621,000	5,600,000	481,000	5,800,000	N.A.	N.A.
Rhude & Fryberger Inc.	Rana	—	570,457	—	742,923	369,610	468,656	N.A.	N.A.
	Sharon[8]	302,897	321,154	107,969	—	—	—	N.A.	N.A.
J.R. Simplot Minerals & Chemicals Div.	Conda	1,138,503	4,038,645	1,580,083	5,421,755	1,500,000	4,500,000	1,910,000	8,120,000
	Gay	1,604,528	7,559,122	1,796,129	8,393,934	1,700,000	8,300,000	7,750,000	12,700,000
Smokey Valley Mining Co.	Round Mountain	1,626,462	1,356,445	1,501,640	2,407,990	N.A.	N.A.	1,145,000	4,357,000
Standard Slag Co.	Beck[10]	10,400	—	14,132	—	—	—	—	—
	Atlanta	169,625	129,465	84,840	376,220	108,240	408,275	N.A.	N.A.
	P. & S.	29,681	25,000	52,485	44,500[2]	33,257	149,656	N.A.	N.A.
	Hot Creek	26,916	30,000	22,206	50,000	16,216	45,000	N.A.	N.A.
	Siltex	2,811	3,000	—	—	872	—	—	—
	Pacific	963	6,000	1,690	—	—	—	—	—
Texasgulf Inc.	Lee Creek	3,514,100	8,550,000	4,586,000	9,500,000	10,110,372	30,659,517	8,835,000	33,367,000
Titanium Enterprises	Titan	N.A.	3,240,000[1]	—	—	—	—	—	—
Union Carbide	Gas Hills	519,376	18,049,885	476,000	12,060,000[1]	465,700	23,140,000[1]	N.A.	N.A.
	Hot Springs	—	—	136,000	163,000	165,000	400,000	N.A.	N.A.
	King City	—	—	—	—	104,000	143,000[1]	N.A.	N.A.
UV Industries Inc.[5]	Continental Mine	355,517	843,981	1,441,442	860,797	1,711,489	934,072	1,440,862	4,294,223
U.S. Borax & Chemical Corp.	Boron	3,400,000[4]	11,700,000[2]	3,424,370	12,651,500	3,585,286	20,798,780	N.A.	N.A.
U.S. Steel Corp.	Rouchleau	162,000	N.A.	—	—	—	—	—	—
	Minntac[6]	41,704,746	N.A.	56,088,087	12,775,131	49,000,000	11,394,379	42,369,406	14,800,000
	Sherman	1,203,000	N.A.	—	49,813	—	—	194,276	N.A.
	Atlantic City[4]	4,515,000	7,100,000[1]	4,347,000	3,487,000[1]	4,631,000	3,377,000[1]	4,610,000	4,186,000[1]
	Desert Mound	1,367,000	1,004,000	584,000	2,160,000	13,000	134,000	N.A.	N.A.
	Plummer	1,730,000	N.A.	N.A.	N.A.	—	—	—	—
	Averturas	1,314,000	N.A.	N.A.	N.A.	380,268	893,646	N.A.	N.A.
Utah International Corp.	Iron Springs[12]	704,556	N.A.	—	—	—	—	—	—
Western Nuclear, Inc.	McIntosh	258,356	2,100,000	304,856	1,900,000[1]	N.A.	N.A.	N.A.	N.A.
	Sherwood	348,850	7,488,401[1]	700,000[2]	N.A.	N.A.	N.A.	N.A.	N.A.

N.A. Not available. 1. Cubic yards. 2. Estimated. 3. Formerly National Lead Company. 4. Closed September, 1977. 5. Formerly United States Smelting and Refining Company. 6. Four month strike in 1977. 7. Operations ceased at end of 1979. 8. Mine resumed operations after 21 months of shutdown. 9. Shut down for 1 year. 10. Closed 1980. 11. Closed 1978. 12. Closed 1979. 13. Includes Eisenhower stripping. 14. Closed 1981. 15. Includes Blue Star.



BINGHAM CANYON, the world's largest open pit, produced 39,024,000 tons of ore and 134,274,849 tons of waste in 1981. It set a record of 638,649 tons in February 1981.

pany's Borealis mine started leaching in October, after only a few months' development and construction. By year-end 104,000 tons of ore were mined.

Freeport Gold Company's Jerritt Canyon mine and cyanide mill reached production status in September and treated 517,000 tons of ore. Stripping tonnage is not available.

Two new copper molybdenum mines started production during the year. One mine, Anaconda Mining Company's Tonopah (Hall) mine north of Tonopah, Nevada, produced 44,397,000 tons of waste and 1,186,000 tons of ore. Metallurgical problems and low metal prices hampered this operation. At the second mine, the Quintana Minerals Corporation stripped 5,300,000 tons of waste at its Hillside pit in New Mexico. Milling started in April 1982.

Cyprus Mining Corporation started stripping at its new Thompson Creek molybdenum pit in Idaho during mill construction. By the year-end some 12,000,000 tons of waste had been mined.

Several major phosphate mines were under development during the year. In North Carolina, a new mine is being developed near Aurora by the North Carolina Phosphate Company. Several companies were seeking operational permits for and planning new mines in Florida. Environmental restrictions will be severe for these mines.

J. R. Simplot Company completed its Environmental Impact Statement for its proposed new Smokey Canyon phosphate mine in Idaho.

Montana will get another major open pit gold mine. Placer Amex Inc., a subsidiary of Placer Development Limited, of Canada received a development permit and started preparation for its Golden Sunlight low grade gold deposit.

For many years, the big five open pit metals have been copper, taconite, phosphate, iron ore, and uranium. Now there are six major open pit metals as gold has been added to the other five.

The Carlin Gold Mining company has, for many years, operated several large pits in Nevada. See the adjoining table for ore and waste mining rates. In 1981, there were eight other high tonnage gold pits: five in Nevada, two in Montana, and one in New Mexico.

Largest gold pit was the Cortez mine of Cortez Mines Corporation in Nevada where 1,394,000 tons of ore were produced. Another major Nevada gold mine is the Round Mountain mine, owned by Smokey Valley Mining Company, which has produced 1,145,000 tons of ore and 4,357,000 tons of waste. The third largest gold pit is the Zortman pit in the state of Montana where Argus Gold Mining Inc. mined 1,096,000 tons of ore and 1,191,000 tons of waste. At the nearby Landusky mine, 951,000 tons of ore were mined and placed on leach piles, with 116,000 tons added to stockpiles. Total waste stripped was 982,000 tons. Gold Fields Mining Company mined 980,000 tons of ore and 300,000 tons of waste (World Mining estimate) at its Ortiz pit in New Mexico. The Round Mountain, Zortman, Landusky, and Ortiz pits all produce very low grade ores for heap leaching.

Yet another major Nevada gold miner is the Pinson Mining Company which mined a total of 4,414,048 tons during the year. Waste totaled 3,898,570 tons, the RIP mill treated 323,910 tons, and 191,568 tons of low grade ore were added to leach piles.

Carlin Gold Company, for many years the major Nevada gold miner, operated four pits in 1981. Heretofore, the company released individual production figures for each mine. However, for 1981 only total production figures are available. They are 787,000 tons of ore and 9,613,000 tons of waste.

With the closure of the Questa pit of Molycorp Inc., the only open pit molybdenum mine in the United States is at Climax, Colorado. Operated by Amax, Inc. (Climax Molybdenum Company), the mine had a record 21,649,878 tons of waste stripped and 5,933,560 tons of ore mined.

Minnesota taconite mines are always very large mines and 1981 continued this pattern. Major mining companies and their production were:

- United States Steel Corporation, the Minntac mine—42,396,406 tons of ore, 14,800 000 waste, total 57,196,406;
- Hibbing Taconite Company (Pickands Mather), Hibbing—27,992,204 tons of ore, 8,000,000 waste, total 35,992,204;
- Reserve Mining Company, the Peter Mitchell mine—25,991,680 tons of ore, 5,765,897 waste, total 31,757,577;
- Erie Mining Company (managed by Pickands Mather), Hoyt Lake mine—23,772,662 tons of ore, 21,569,342 waste, total 45,342,004;
- Eveleth Taconite Company, the Thunderbird mine—18,409,634 tons of ore, 12,500,000 waste, total 30,909,634.

By far the largest mine in the United States, and probably in the world, in 1981 was the Utah Copper Division of Kennecott Corporation in Utah where an all time record high of 171,298,849 tons were mined. Ore was 39,024,000 tons, also a record, and waste mined was another record at 134,274,849 tons.

Second largest, and it has been the largest in total tons mined during some years, was the Sierrita mine of Duval Corporation in Arizona. Ore mined totaled 32,614,300 tons and waste mined was 35,742,400 for a total of 68,356,700. Other large copper mines in descending order of production were Morenci; Pinto Valley; Tyrone; Ray; Cyprus Bagdad; Cyprus Pima; and Twin Buttes.

Note that the Chino copper mine in New Mexico is now owned by the Chino Mines Company, a partnership of Kennecott Corporation and Mitsubishi Corporation of Japan. Total production and Kennecott's share was 6,386,070 tons of ore (5,406,000) and 42,132,871 waste (33,854,046). ■

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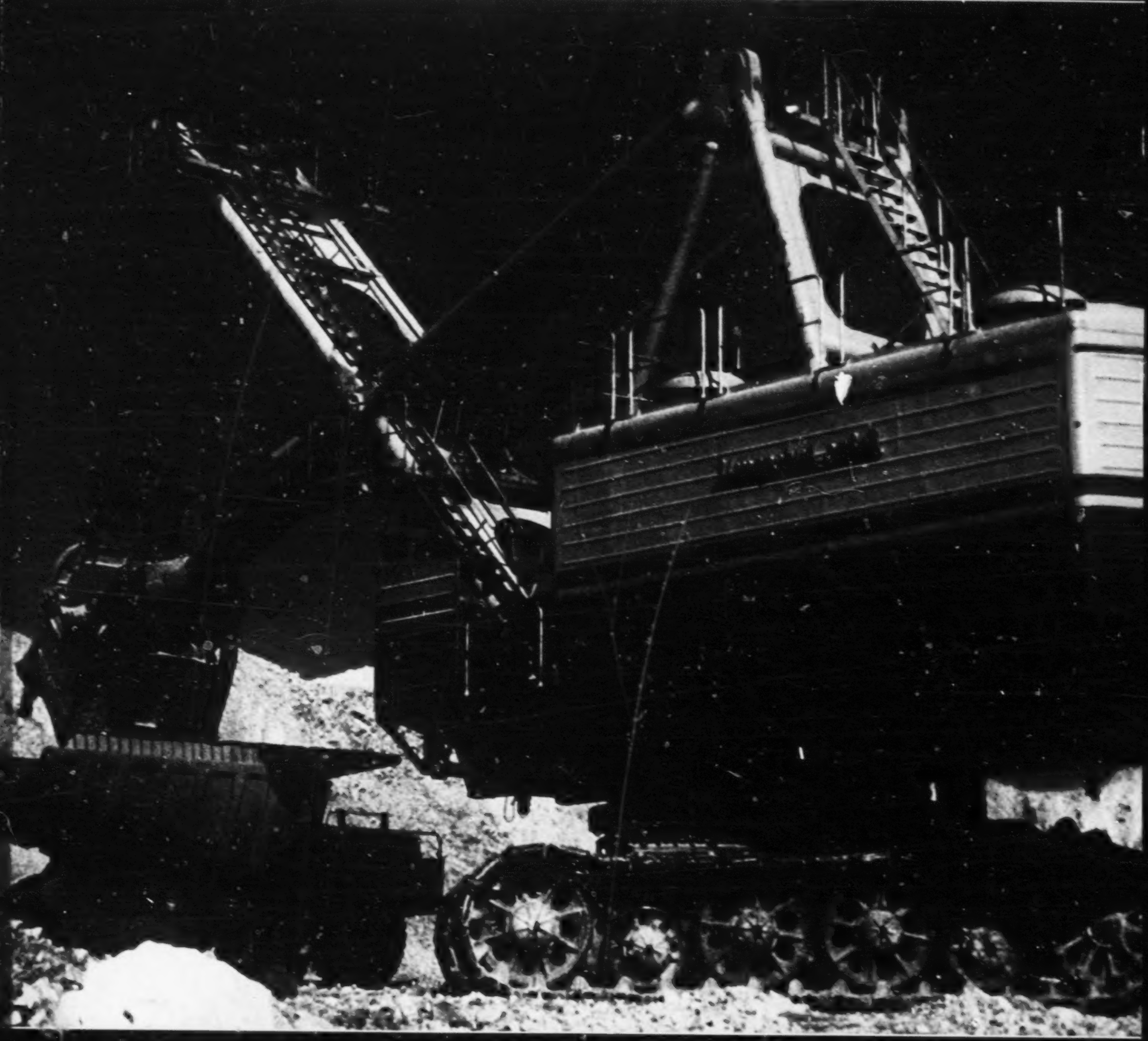
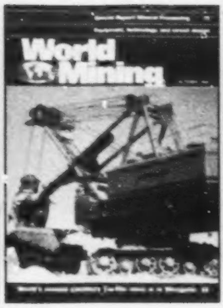


World's newest porphyry Cu-Mo mine is in Mongolia 58



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THE COVER

A CBCh-250MN shovel loads a BelAZ-548-A truck at the Erdenet, Mongolia mine. Truck capacity does not match shovel loading capacity. With the gently sloping muck pile, the truck backs into the bank, so that the shovel has only to make a quarter swing for loading. *Photograph by Audrey Topping.*

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After THOUGHTS

In the next twenty years, capital investment for production of one metal will total $95,500,000,000. During the same period, demand for this metal will more than double—from 18,000,000 tons per year to approximately 38,000,000 tons per year. Real prices for this metal will increase by some 15 percent.

What is the metal? And who says so? The metal—aluminum. The projections have been made by Chemical Bank, a leading United States financial institution in a recent publication, "Aluminum: The Next Twenty Years." As editors, we have stacks of mail come across our desks every day. Recently, quite frankly, there has not been a great deal of good news or even optimistic news, so it was rather exciting to read through this Chemical Bank forecast for aluminum.

Demand for aluminum is expected to expand more rapidly than that for any other base metal. Demand is forecast to rise by 4 to 5 percent per year over the next twenty years. The report concludes that current planned capacity will be sufficient to meet demand through 1985. Beyond that, additional installed capacity of approximately 1,000,000 tons per year will be required. In terms of mining, this means a production capacity increase from 97,500,000 tons of bauxite per year to 187,000,000 tons per year.

Large production increases for aluminum will not require large exploration expenditures, as is the case for other base metal deposits. Known world bauxite reserves are large enough to supply demand for some 250 years. Over 50 percent of known reserves are in three countries: Guinea (5,900,000,000 tons), Australia (4,600,000,000 tons), and Brazil (2,300,000 tons). The largest bauxite producer today, Jamaica, accounts for 8.9 percent of total reserves, or 2,000,000 tons.

It is not surprising, then, that of the projected capital investment of $95,500,000,000 over the next twenty years, some $30,000,000,000 is projected for projects in Brazil and about $24,000,000,000 for Brazil and Guinea combined. For both Brazil and Australia, capital cost per ton of aluminum produced is relatively low on world terms as can be seen in Table 1. Additionally, relatively inexpensive hydroelectric power in Brazil and Guinea and coal generated power in Australia will make these countries attractive locations not only for bauxite mining, but for alumina refining and aluminum smelting as well.

About two years ago, there was euphoria over the expected aluminum boom in Australia. Within the past several months, though, this enthusiasm has dampened as a result of lighter demand for aluminum in the face of the current worldwide recession. Chemical Bank, though, believes that this is a short term slowdown and the Australian aluminum industry will reach prosperity, albeit perhaps at a slower pace than originally envisioned.

Another trend that Chemical Bank sees is a shift of future alumina refinery construction closer to mine sites. Rising transportation costs will make it more attractive to refine bauxite to alumina rather than shipping bauxite to remote alumina refineries, because about 2½ tons of bauxite are required to produce 1 ton of alumina. Another factor which will contribute to mine-mouth refineries is the trend in countries such as Brazil and Guinea to more completely integrate their aluminum industry, thereby increasing unit revenue for these countries.

Table 1. Comparative costs of aluminum production

	Total Cost of New Smelter Projects	Long Run Marginal Costs of Supply[1]	
		Low	High
U.S.	2170	1950	2000
Canada	1895	1930	1980
Brazil	1730	1916	1970
W. Europe	2180	1900	2000
Australia	1740	1914	1971
Middle East	1805	1860	1925
Japan	2120	2110	2176

Source: World Bank. 1. 1980 dollars per metric ton

Table 2. Geographic distribution of production, 1980[1]

Area	Bauxite	Alumina	Primary Aluminum
Europe (incl. USSR)	20.9	32.6	44.2
Africa	14.0	2.0	2.2
North America	2.4	23.3	36.6
South America	26.1	12.8	2.5
Asia	5.8	7.6	11.7
Australia, Oceania	30.8	21.7	2.8

Source: Metal Bulletin Aluminum Congress 1980. 1. Percentages of world total

The trend toward locating refineries closer to the mines will probably be the same with regard to aluminum smelters, although the primary determinant of where to construct smelters is cheap energy, which accounts for 25 to 30 percent of total aluminum production costs. Distribution of bauxite, alumina, and aluminum smelter production worldwide is shown in Table 2. It is clear to see that at present, the location of mines, alumina refineries, and aluminum smelters do not correlate that closely.

The growth in aluminum demand over the past several years has resulted from the substitution of this metal for alternative materials such as steel, wood, plastic, glass, paper, and cardboard. There is no reason to believe that this trend will not continue.

While aluminum producers and consumers as well as financial institutions may differ with the projections made by Chemical Bank, this bank should be commended for reports such as this one, which incorporates a great deal of useful information on an important segment of the mining and metallurgical industry. It is through sharing of such information that mining companies can better plan for the future, not only as individual corporations, but as an international industry.

Information on this and other mineral commodity reports can be obtained from Gerald Pollio, Chemical Bank, 277 Park Avenue, New York, New York 10172, United States. *—DAP*